


Use of Text Mining Techniques for Recommender Systems

Yanelys Betancourt¹ and Sergio Ilarri² 

¹Universidad de Zaragoza, Edificio Ada Byron, María de Luna, 1, 50018 Zaragoza, Spain

²IA, Universidad de Zaragoza, Edificio Ada Byron, María de Luna, 1, 50018 Zaragoza, Spain

Keywords: Recommender Systems, Text Mining, Opinion Mining.

Abstract: Recommender systems help users to reduce the information overload they may suffer in the current era of Big Data, by offering them recommendations of relevant items according to their tastes/preferences and/or context (location, weather, time of the day, etc.). We argue that text mining techniques can be exploited for the development of recommender systems. Thus, they can be applied to detect user preferences (user profiling) and also to extract context data. For this purpose, text mining can be applied on user reviews, text descriptions associated to the items, and other texts written by the user (e.g., posts in social networks). In this paper, we provide an overview of works exploiting text mining techniques in the field of recommender systems, characterizing them according to their purpose and the type of textual data analyzed.


1 INTRODUCTION

Nowadays, *recommender systems* (RS) (Ricci et al., 2011; Ricci et al., 2015) have become very popular, as they can help users to reduce the information overload they may suffer in today's Big Data era, where advanced data management techniques are required. These systems provide recommendations to the users according to their tastes and preferences, allowing them to filter, from a great amount of different types of items (e.g., music, movies, news, books, places, services, shopping areas, restaurants, points of interest, etc.), those that can be of special relevance to them. Given their current specialization, recommender systems keep being a hot area of research. In mobile environments in particular, recommender systems that take into account not only the user's preferences but also their context (location, time, weather, traffic conditions, etc.) are of particular interest, which has given rise to the so-called *context-aware recommender systems* (CARS) (Adomavicius and Tuzhilin, 2011).

We argue that the use of text mining techniques (Berry, 2004; Gupta et al., 2009) can be exploited for the development of recommender systems from various perspectives. Popular text mining tasks include text clustering, text classification, information extraction, text summarization, sentiment analysis/opinion mining, etc. For example, sentiment anal-

ysis techniques could be applied to quantify user preferences based on their comments expressed in natural language or even to detect possible inconsistencies (opinion spam) if a user provides both a textual comment and a numerical rating (mining of opinions about items). In addition, they can be used to exploit textual descriptions of the different elements to recommend (mining of items' textual data). Finally, the possible analysis of other texts written by the user himself/herself (e.g., in blogs, social networks, his/her agenda, etc.) may reveal information about his/her preferences, interests, and even his/her context.

A relevant complement of text mining techniques is the use of semantic techniques, usually based on the use of ontologies. As an explicit formal specification of a shared conceptualization (Gruber et al., 1993), an ontology contains a shared vocabulary to denote the types, properties and interrelations of those concepts (Subramaniaswamy et al., 2019). Besides the possibility to use ontologies as a support for data mining tasks such as information extraction, ontologies can also be exploited directly by a recommender system (Subramaniaswamy et al., 2019; Tarus et al., 2018), for example to establish the relationships between users and their preferences on the recommendation topic (Tarus et al., 2018). Ontology-based recommender systems using text mining often use a topic ontology with associated controlled vocabulary to identify topics from text messages written in nat-

^a  <https://orcid.org/0000-0002-7073-219X>

ural language (comments, descriptions, opinions, reviews, etc.).

In this paper, we provide an overview of works that exploit text mining techniques in the field of recommender systems (see Figure 1). The structure of the rest of this paper is as follows. In Section 2, we focus on works in the field of recommender systems that apply text mining techniques on user reviews. In Section 3, we consider recommender systems that perform text mining on other texts written by the user. In Section 4, we consider works using textual data about the items themselves. Finally, in Section 5, we summarize our conclusions and future work.

2 RECOMMENDER SYSTEMS USING TEXT MINING ON USER REVIEWS

In this section, we focus on text mining of user reviews (see Table 1). Sometimes users provide opinions about the items they consume, through text descriptions posted in blogs, microblogs (like Twitter), product review websites, chat rooms, online feedback systems of companies, and different user communities or social networks (such as Facebook, Twitter, LinkedIn, or Instagram). These opinions contain very valuable information to detect the interests of the users, which can be exploited for recommendation purposes (Roul and Arora, 2019; Kim and Chun, 2019).

As these opinions are provided in natural language, they cannot be directly exploited to learn the user preferences and recommend the user other items that he/she is expected to like. Therefore, a typical use of text mining for recommender systems is to try to transform textual user reviews into scores (e.g., in a range of 0 to 5) or predefined categories such as *positive opinion*, *neutral opinion*, or *negative opinion*, that can be used to build the user-item matrices that recommender systems use in the recommendation process; specifically, sentiment analysis or opinion mining techniques (Liu and Zhang, 2012; Hegde and Padma, 2017) can be applied.

In (Acıar et al., 2007), text mining techniques are used to transform opinions into structured data, using a translation ontology that encompasses both the user's skill and the user's experience with the product. Scores for each feature are computed in order to rank the products according to the comments available about that product. The system requires users to explicitly request a recommendation/assessment about a specific product they are interested in, and they have

to select the features that interest them most. Beyond that, it should be noted that this type of recommendation is not personalized, as the individual preferences of the user are not considered when making the recommendation. The proposal takes into account the level of experience of the reviewers to ensure a reliable recommendation.

The reliability of the reviews is also a key aspect considered in other proposals. Thus, (Abuein et al., 2017) presents the design and implementation of a recommender system based on information provided by trusted people using the concept of *trust level (LoT)* (Abuein et al., 2016). In (Roul and Arora, 2019), the reviewer's credibility is also considered, but in this case the focus is on generating summaries of multiple reviews for a given product and the credibility (computed by analyzing how much the reviewer's rating deviates from most people's ratings) is used to decide on the importance of a sentence. For the automatic summarization of user reviews, fuzzy c-means clustering is used to group similar sentences and then one representative sentence from each group is selected in order to compose the final summary. This work's goal is to generate a representative summary of reviews to provide along with the recommendation of a product, rather than proposing a novel recommender system.

In (Musto et al., 2019), the authors present an approach to generate natural language justifications to support the suggestions returned by a generic recommendation algorithm, based on natural language processing and sentiment analysis techniques to identify the relevant and distinctive aspects that characterize an item. The experimental results included in the paper show that the justifications generated can be rich and satisfying and that the users prefer review-based justifications as opposed to other explanation strategies (feature-based explanations); in particular, the authors' proposal is compared experimentally with ExpLOD (Musto et al., 2016). As a final example, a recommender system applying text mining on opinions written in Chinese is presented in (Miao and Lang, 2017). An item-feature matrix is built to calculate the similarity of item characteristics, with the goal to improve the accuracy of item similarity and so the quality of the recommendations. A technique called *ItemCF* is used to generate the recommendation (Shi et al., 2014), which supports the pre-calculation of similar items.

There are other works that exploit both numerical ratings provided by the users and textual user reviews, based on the hypothesis that this joint use can lead to more accurate recommendations. Thus, in (Jakob et al., 2009), that focuses on the domain of movies,

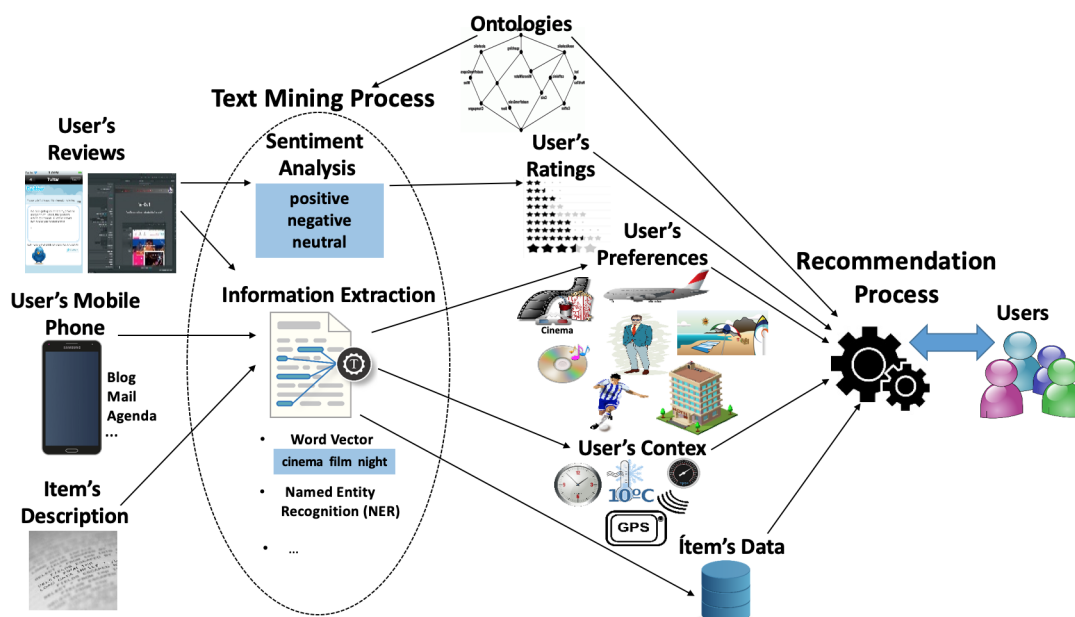


Figure 1: Using text mining in recommender systems: general framework.

a phrase-level opinion extraction from free-text film reviews is performed to identify statements with positive and negative opinions, and this information is incorporated into a recommender system called *HYRES (HYbrid REcommendation System)*. Several movie aspect clusters are defined and global numerical values are computed for each cluster. The experimental results show that the Latent Dirichlet Allocation (LDA) clustering approach leads to the best results.

User reviews could also be analyzed to extract contextual information. For example, (Li et al., 2010), which focuses on reviews about restaurants, uses text mining techniques to extract information about 4 different context attributes: companion (whether the user is alone or with other people), occasion for the event (e.g., whether it is a holiday or a birthday), time of the day, and location (in this case extracted from the user profile, as the authors argue that it is usually not available in the review texts). Then, the authors propose a *Probabilistic Latent Relational Model (PLRM)* to integrate the context data and provide the recommendations.

3 RECOMMENDER SYSTEMS USING TEXT MINING ON OTHER USER'S TEXTS

In this section, we review works that mine textual data written by the user (other than reviews about items, which were already analyzed in Section 2) in order

to retrieve useful information for the recommendation process (see Table 2). This could mean analyzing texts to obtain information about the user's context, such as his/her location (Drymonas and Pfoser, 2010; Feldman et al., 2015), and/or information about his/her preferences (e.g., the topics he/she is interested in). The input textual data could be, for example, tweets written by the user. Besides, many recent studies have begun to explore other sources of information, such as social networks, where larger text messages can be posted and shared. The diary of the user could be another relevant text source. Finally, several recent studies have also demonstrated the effectiveness of leveraging collective knowledge to enrich the users' interest profiles (Faralli et al., 2015).

Twitter can be an interesting data source to try to infer the interests of users (Piao and Breslin, 2018). As an example (Xu et al., 2011), starts from the idea that users often post noisy messages about their lives or create conversations with friends that are not really related to their topics of interest. Therefore, they propose a framework to address this problem by introducing a modified author-subject model called the Twitter user model, which is a generative model that extends LDA to include information about authorship. A latent variable is used to indicate if a tweet is related to the author's interests. According to the authors, this model can be considered as an initial work for many tasks in Twitter, such as recommending friends, rating users, and analyzing social networks. As another example, in the proposal presented in (Zarrinkalam et al., 2015) each topic of interest is a conjunction of

Table 1: Examples of recommender systems using text mining on user reviews.

Items	Data used	Recommendation Approach	Supporting tools	Text mining techniques	Reference
Products	Reviews	Collaborative Filtering	Ontology, measures such as the OFQ (Overall Feature Quality)	Rule-based classification techniques, TMSK (Text-Miner Software Kit), Riktext software, ontology (opinion quality and product quality).	(Aciar et al., 2007)
Items	Reviews (written in Chinese)	Collaborative Filtering	Euclidean distance, ItemCF (Shi et al., 2014)	Word segmentation (jieba), stop words removal, POS Templates, HowNet (emotional dictionary), clustering, chi-square statistics, logistic regression	(Miao and Lang, 2017)
Tourist attractions	Reviews	Knowledge-based	Supervised algorithms Probit algorithm, binomial logistic regression, decision trees (CHAID, C&RT and Random Forest)	IBM SPSS Modeler Text Analytics, removing non-linguistic entities	(Guerreiro and Rita, 2019)
Shoppings	Reviews	TRS.LoT (approach based on the trust level)	LoT (Level of Trust)	Stop-word removal, word indexing, word comparison	(Abuein et al., 2017)
Movies	Reviews, ratings	Collaborative Filtering	HYRES recommender	Clustering, stop word removal, Explicit Semantic Analysis (ESA), LDA-based clustering, subjectivity clue lexicon	(Jakob et al., 2009)
Restaurants	Restaurant's review	CARS (recommendation based on contextual information)	Boolean model, Probabilistic Latent Relational Model (PLRM)	Bag of words, rule-based classifiers, GATE tools (ANNIE, which is a time named entity recognizer)	(Li et al., 2010)

several concepts, which are temporarily correlated on Twitter. Based on this, active themes within a given time interval are extracted and the user's inclination towards those themes is determined. Based on this idea, a concept graph is built and community detection methods are applied to detect active topics of interest in a given time interval, considering that the relationships between two topics in a social network can change over time. Besides, a technique to determine the standpoint of a given user with respect to the active topics is proposed. The proposal presented was applied to design a personalized news recommender system, which was evaluated experimentally.

Due to the existing information overload in Twitter, recommender systems have also been created to recommend useful tweets in which users could be really interested. For example, in (Chen et al., 2012), the following elements are considered for the recommendation: factors related to the thematic/topic level of the tweet (used to capture users' common interests in the content of the tweets), factors of the social rela-

tionships of the user, and explicit characteristics such as the authority of the editor and the quality of the tweet. The experimental results show that the combination of all these elements can help to improve the performance of tweet recommendations.

Besides tweets, another popular type of user-written data can be text messages posted on social networks. *KBRs* (Rosa et al., 2019) is a knowledge-based recommender system that, based on ontologies and the analysis of feelings, is able to analyze sentences published on online social networks with the purpose of detecting users with potential psychological disorders (depression and stress). Then, if needed, a recommender system is used to send messages of happiness, calm, relaxation, or motivation. Text sentences are analyzed using machine learning algorithms, including the CNN model, BLSTM-RNN, and considering the feeling metric (eSM2). eSM2 was modeled to improve the performance of *KBRs*, taking into account parameters of the user profile, his/her geographic location, and the subject of the sentence,

Table 2: Examples of recommender systems using text mining on other user's texts.

Items	Data used	Recommendation Approach	Supporting tools	Text mining techniques	Reference
Tweets	Tweets, user social relations and other features	Collaborative Filtering	Factorization model, Jaccard similarity	Latent factors	(Chen et al., 2012)
Messages	Messages, user profile parameters, geographical location	Knowledge-based	Deep Learning, recurrent neural networks (RNN), BLSTM-RNN model, the Nuadu ontology	Machine learning algorithms, sentiment metric (eSM2)	(Rosa et al., 2019)
Tourism POIs	Textual messages in a web chat	Content-Based Filtering	Probabilistic techniques (fuzzy reasoning) ontology	Rocchio's and Naive Bayes algorithms, tourism ontology	(Loh et al., 2003)
Tags	Text in tags	Collaborative Filtering	Association rules, LDA	TF-IDF	(Krestel et al., 2009)

to identify the intensity of the feeling identified in a message. The paper shows the effectiveness of using an ontology and a personalized feeling analysis.

Text mining techniques can also be used to discover user interests from text exchanged in a chat conversation. For example, (Loh et al., 2003) exploits texts in chats between a customer and a travel agent to discover and recommend travel options for customers, especially for those who do not really know where to go and what to do there. The proposed system queries a tourism ontology to identify key topics in the text messages and then queries a database to retrieve appropriate touristic options (such as cities and attractions). In this case the recommender system is hidden from the customer, as it is the travel agent the one who receives the recommendations, that support him/her to better guide the client. Rather than using extensive forms with options, attributes, and requirements, the needs and desires of the customer arise during a natural conversation, and the data retrieved by the system can complement the potential lack of experience or knowledge of the travel agent regarding the specific interests of the customer.

Some work has also been done to extract information from texts written by users in informal communications (instant messaging, recordings, meeting minutes, emails) as a potential source of knowledge within an organization. This could be very useful, for example, to create user profiles for use in recommender systems. In (Gentile et al., 2011), the authors claim that it is possible to model the experience of people automatically by tracking informal communication exchanges (e-mails) and through the semantic annotation of their content to derive dynamic user profiles. The profiles are then used to estimate the similarity between people (using the Jaccard index). A tool called *SimNET (Similarity and Network Exploration Tool)* interactively displays content and user

networks as part of the search and navigation capabilities provided by the knowledge management system. Three techniques are used to build the profiles: *Profile based on keywords*, using the Java Automatic Term Recognition Toolkit (JATR v1.02) for keyword extraction; *Profile based on the Entity*, using the Open Calais web service for the extraction of named entities; and *Profile based on the Concept*, using the Wikify web service for concept extraction.

Another relevant type of written text that can be considered is text present in tags. Tagging systems have become important for the Web, as they allow users to create tags that annotate and categorize different types of contents and share them with others. However, an important difficulty is that tags are not limited by a controlled vocabulary and annotation guidelines, and they tend to be noisy and sparse. The aim of the approach presented in (Krestel et al., 2009) is to overcome the problem of cold start for tagging new resources. Specifically, LDA is used to obtain latent topics from texts and, based on this, other tags belonging to those themes can also be recommended. According to the experimental evaluation presented, this approach achieves a better performance (in terms of accuracy and recall) than an alternative approach using association rules.

4 RECOMMENDER SYSTEMS USING TEXT MINING ON ITEMS'S DATA

In this section, we review some works that apply text mining on data associated to the items that can be recommended (see Table 3).

With geo-positioning and geo-tagging of objects that have both a geographic location and a text de-

Table 3: Examples of recommender systems using text mining on item's data.

Items	Data used	Recommendation Approach	Supporting tools	Text mining techniques	Reference
Tourism POIs	Keywords, GPS location, POIs' descriptions	ReCoSKQ	CoSKQ	Any text mining technique	(Hermoso et al., 2019)
Apps	Version metadata, textual descriptions	Hybrid	Semi-supervised topic model, PMF, LDA	Topic-word distribution, latent topics	(Lin et al., 2014)
Apps	Context's description, app's title and description, app's metadata	IR-based (context-aware) approach	Lucene search engine, Context-Aware Browser (Coppola et al., 2010)	TF-IDF, clustering	(Mizzaro et al., 2014)
Events	GPS location, news	Location-aware	Learning model disambiguation and matching	sLDA, SVM (polynomial, Gaussian, lineal)	(Ho et al., 2012)

scription, the so-called spatial keyword queries that exploit both the locations and the text descriptions are attracting growing attention (Cao et al., 2011). More specifically, the aim of a *Collective Spatial Keyword Query (CoSKQ)* is to retrieve, from a spatial database, a group of spatial elements in such a way that the description of the elements included in that set, based on keywords, is completely covered by the keywords of the query and also that the elements retrieved are as close as possible to the location of the query and have the smallest possible distances between the elements themselves. In (Hermoso et al., 2019), the authors argue that the use of this concept could be useful for the development of recommender systems for tourism, in order to provide the user with a set of points of interest (POIs) that satisfy his/her query (e.g., a query expressing his/her current interest or need) both geographically and semantically; the idea of Re-CoSKQ is presented, which is an adaptation of CoSKQ for the field of recommender systems. Although text mining techniques are not explicitly applied in Re-CoSKQ, they are expected to be needed as a pre-processing step, in order to obtain the keywords that describe the different items and/or the user profile.

A recommender system of mobile applications that exploits the description of the application and associated metadata is presented in (Lin et al., 2014). As an updated version of an app may bring significant changes, it first generates latent themes from the version's features using a semi-supervised theme model to characterize each version. Themes are discriminated based on metadata and a recommendation technique called *VSR (version-sensitive recommendation)* is proposed. For experimental evaluation, two alternative recommendation approaches are considered as baselines: probability matrix factorization (PMF), which is a collaborative filtering (CF) technique, and LDA, which is a content-based filtering

(CBF) technique. The authors show the accuracy of the recommendations obtained when these techniques are used independently and also when they are combined (CF+CBF, CF+VSR, CBF+VSR, and CF+CBF+VSR). This work reports that a hybrid recommender system incorporating the version-sensitive model proposed achieves better results.

Other mobile app recommender systems also take into account the context of the user. Thus, *App-CAB* (Mizzaro et al., 2014) is a recommender system of mobile apps that provides a proactive and fully automated procedure for querying the mobile app market, capable of retrieving a set of applications and classifying them according to the user's current situation. The description of the user's context is generated by a *Context-Aware Browser* (Coppola et al., 2010) to find the suitable applications for the user's needs in that specific context. To categorize contexts, all the words in the title and description of the applications that have the same category are grouped, creating several sets of words that represent the categories of the market. The word indexing process is performed using Lucene to build a category index. When the system analyzes the current context, it checks each word that describes the context in the index in order to compute relevance scores and obtain a list of potentially-relevant categories. In this way it is possible to weigh the pertinence of different types of applications for the given context. Besides, if a word that appears in the context is part of the title of the application, then +10% is added to the original score, to emphasize the importance of a match at the level of the application name. Finally, a filtering step is applied to eliminate duplicate results before presenting them to the users.

Finally, in (Ho et al., 2012), an approach to extract future space-time events from the Web, to be used as candidate items in a location-aware recommender system of events, is presented. This work proposes

a procedure for the extraction of events from news articles, which consists of two main steps: recognition and matching. In the recognition stage, place names and future time patterns are identified and extracted. In the matching stage, operations for spatial-temporal disambiguation, de-duplication and matching, are performed. A sentiment variable (positive, negative or neutral) is attached to each event, as an aid for the recommendation application. So, the future event identified consists of its geographic location, time pattern, sentiment variable, news title, key phrase, and URL of the news article.

5 CONCLUSIONS

In this paper, we have provided an overview of works exploiting text mining techniques in the field of recommender systems, characterizing them according to the type of textual data analyzed (user reviews, other texts written by the user, or textual data associated to the items) and considering their purpose (extract information about the context of the user or perform user profiling).

Beyond user reviews, exploiting other types of texts written by the user seems to be an area that remains quite unexplored, particularly concerning more personal textual data such as emails received or sent, the user's personal agenda, or the user's diary; this could be partly due to privacy concerns. Besides, most works focus only on a specific type of text. As future work, we intend to propose an integrated approach that combines and adapts several text mining techniques as a support tool to build a context-aware recommender and evaluate its performance.

ACKNOWLEDGEMENTS

This work has been supported by the project TIN2016-78011-C4-3-R (AEI/FEDER, UE) and DGA-FSE (COSMOS research group).

REFERENCES

- Abuein, Q., Shatnawi, A., and Al-Sheyab, H. (2017). Trusted recommendation system based on level of trust (TRS.LoT). In *2017 International Conference on Engineering and Technology (ICET)*, pages 1–5.
- Abuein, Q., Shatnawi, M., Bani Yassein, M., and Batiha, R. (2016). A framework for social media and text-based content analysis for event management purposes. *International Review on Computers and Software*, 11:388–394.
- Aciar, S., Zhang, D., Simoff, S., and Debenham, J. (2007). Informed recommender: Basing recommendations on consumer product reviews. *IEEE Intelligent Systems*, 22(3):39–47.
- Adomavicius, G. and Tuzhilin, A. (2011). *Recommender Systems Handbook*, chapter Context-Aware Recommender Systems, pages 217–253. Springer US, Boston, MA.
- Berry, M. W., editor (2004). *Survey of Text Mining*. Springer New York.
- Cao, X., Cong, G., Jensen, C. S., and Ooi, B. C. (2011). Collective spatial keyword querying. In *ACM SIGMOD International Conference on Management of Data (SIGMOD 2011)*, pages 373–384, New York, NY, USA. ACM.
- Chen, K., Chen, T., Zheng, G., Jin, O., Yao, E., and Yu, Y. (2012). Collaborative personalized tweet recommendation. In *35th International ACM SIGIR Conference on Research and Development in Information Retrieval (SIGIR 2012)*, pages 661–670. ACM.
- Coppola, P., Della Mea, V., Di Gaspero, L., Menegon, D., Mischis, D., Mizzaro, S., Scagnetto, I., and Vassena, L. (2010). The context-aware browser. *IEEE Intelligent Systems*, 25(1):38–47.
- Drymonas, E. and Pfoser, D. (2010). Geospatial route extraction from texts. In *First ACM SIGSPATIAL International Workshop on Data Mining for Geoinformatics (DMG 2010)*, pages 29–37. ACM.
- Faralli, S., Stilo, G., and Velardi, P. (2015). Recommendation of microblog users based on hierarchical interest profiles. *Social Network Analysis and Mining*, 5(1).
- Feldman, D., Sung, C., Sugaya, A., and Rus, D. (2015). IDiary: From GPS signals to a text-searchable diary. *ACM Transactions on Sensor Networks*, 11(4):60:1–60:41.
- Gentile, A. L., Lanfranchi, V., Mazumdar, S., and Ciravegna, F. (2011). Extracting semantic user networks from informal communication exchanges. In Aroyo, L., Welty, C., Alani, H., Taylor, J., Bernstein, A., Kagal, L., Noy, N., and Blomqvist, E., editors, *The Semantic Web – ISWC 2011*, pages 209–224. Springer.
- Gruber, T. R. et al. (1993). A translation approach to portable ontology specifications. *Knowledge Acquisition*, 5(2):199–221.
- Guerreiro, J. and Rita, P. (2019). How to predict explicit recommendations in online reviews using text mining and sentiment analysis. *Journal of Hospitality and Tourism Management*. DOI: 10.1016/j.jhtm.2019.07.001. In Press, Corrected Proof.
- Gupta, V., Lehal, G. S., et al. (2009). A survey of text mining techniques and applications. *Journal of Emerging Technologies in Web Intelligence*, 1(1):60–76.
- Hegde, Y. and Padma, S. K. (2017). Sentiment analysis using random forest ensemble for mobile product reviews in kannada. In *2017 IEEE 7th International Advance Computing Conference (IACC)*, pages 777–782.

- Hermoso, R., Harri, S., and Trillo-Lado, R. (2019). Re-CoSKQ: Towards POIs recommendation using collective spatial keyword queries. In *ACM RecSys Workshop on Recommenders in Tourism (RecTour 2019), in conjunction with the 13th ACM Conference on Recommender Systems (RecSys 2019), Copenhagen (Denmark)*, volume 2435, pages 42–45. CEUR Workshop Proceedings, ISSN 1613-0073.
- Ho, S.-S., Lieberman, M., Wang, P., and Samet, H. (2012). Mining future spatiotemporal events and their sentiment from online news articles for location-aware recommendation system. In *First ACM SIGSPATIAL International Workshop on Mobile Geographic Information Systems (MobiGIS 2012)*, pages 25–32, New York, NY, USA. ACM.
- Jakob, N., Weber, S. H., Müller, M. C., and Gurevych, I. (2009). Beyond the stars: Exploiting free-text user reviews to improve the accuracy of movie recommendations. In *First International CIKM Workshop on Topic-Sentiment Analysis for Mass Opinion (TSA 2009)*, pages 57–64, New York, NY, USA. ACM.
- Kim, E.-G. and Chun, S.-H. (2019). Analyzing online car reviews using text mining. *Sustainability*, 11(6):1611.
- Krestel, R., Fankhauser, P., and Nejd, W. (2009). Latent Dirichlet Allocation for tag recommendation. In *Third ACM Conference on Recommender Systems (RecSys 2009)*, pages 61–68. ACM.
- Li, Y., Nie, J., Zhang, Y., Wang, B., Yan, B., and Weng, F. (2010). Contextual recommendation based on text mining. In *23rd International Conference on Computational Linguistics (COLING 2010): Posters*, pages 692–700. Association for Computational Linguistics.
- Lin, J., Sugiyama, K., Kan, M.-Y., and Chua, T.-S. (2014). New and improved: Modeling versions to improve app recommendation. In *37th International ACM SIGIR Conference on Research & Development in Information Retrieval (SIGIR 2014)*, pages 647–656, New York, NY, USA. ACM.
- Liu, B. and Zhang, L. (2012). *A Survey of Opinion Mining and Sentiment Analysis*, pages 415–463. Springer US, Boston, MA.
- Loh, S., Lorenzi, F., Saldaña, R., and Licthnow, D. (2003). A tourism recommender system based on collaboration and text analysis. *Information Technology & Tourism*, 6(3):157–165.
- Miao, D. and Lang, F. (2017). A recommendation system based on text mining. In *2017 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC)*, pages 318–321.
- Mizzaro, S., Pavan, M., Scagnetto, I., and Zanello, I. (2014). A context-aware retrieval system for mobile applications. In *4th Workshop on Context-Awareness in Retrieval and Recommendation (CARR 2014)*, pages 18–25. ACM.
- Musto, C., Lops, P., de Gemmis, M., and Semeraro, G. (2019). Justifying recommendations through aspect-based sentiment analysis of users reviews. In *27th ACM Conference on User Modeling, Adaptation and Personalization, UMAP '19*, pages 4–12, New York, NY, USA. ACM.
- Musto, C., Narducci, F., Lops, P., De Gemmis, M., and Semeraro, G. (2016). ExpLOD: A framework for explaining recommendations based on the Linked Open Data Cloud. In *10th ACM Conference on Recommender Systems (RecSys 2016)*, pages 151–154. ACM.
- Piao, G. and Breslin, J. G. (2018). Inferring user interests in microblogging social networks: a survey. *User Modeling and User-Adapted Interaction*, 28(3):277–329.
- Ricci, F., Rokach, L., and Shapira, B. (2011). *Recommender Systems Handbook*, chapter Introduction to Recommender Systems Handbook, pages 1–35. Springer US, Boston, MA.
- Ricci, F., Rokach, L., and Shapira, B. (2015). *Recommender Systems Handbook*, chapter Recommender Systems: Introduction and Challenges, pages 1–34. Springer US, Boston, MA.
- Rosa, R. L., Schwartz, G. M., Ruggiero, W. V., and Rodríguez, D. Z. (2019). A knowledge-based recommendation system that includes sentiment analysis and deep learning. *IEEE Transactions on Industrial Informatics*, 15(4):2124–2135.
- Roul, R. K. and Arora, K. (2019). A nifty review to text summarization-based recommendation system for electronic products. *Soft Computing*, 23(24):13183–13204.
- Shi, Y., Larson, M., and Hanjalic, A. (2014). Collaborative filtering beyond the user-item matrix: A survey of the state of the art and future challenges. *ACM Computing Surveys*, 47(1).
- Subramaniaswamy, V., Manogaran, G., Logesh, R., Vijayakumar, V., Chilamkurti, N., Malathi, D., and Senthilselvan, N. (2019). An ontology-driven personalized food recommendation in IoT-based healthcare system. *The Journal of Supercomputing*, 75(6):3184–3216.
- Tarus, J. K., Niu, Z., and Mustafa, G. (2018). Knowledge-based recommendation: a review of ontology-based recommender systems for e-learning. *Artificial intelligence review*, 50(1):21–48.
- Xu, Z., Ru, L., Xiang, L., and Yang, Q. (2011). Discovering user interest on Twitter with a modified author-topic model. In *2011 IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology*, volume 1, pages 422–429.
- Zarrinkalam, F., Fani, H., Bagheri, E., Kahani, M., and Du, W. (2015). Semantics-enabled user interest detection from twitter. In *2015 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT)*, volume 1, pages 469–476.