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Contents

Extracting, Mining and Predicting Users' Interests from Social Media

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ABSTRACT

The abundance of user generated content on social media provides the opportunity to build models that are able to accurately and effectively extract, mine and predict users' interests with the hopes of enabling more effective user engagement, better quality delivery of appropriate services and higher user satisfaction. While traditional methods for building user profiles relied on AI-based preference elicitation techniques that could have been considered to be intrusive and undesirable by the users, more recent advances are focused on a non-intrusive yet accurate way of determining users' interests and preferences. In this monograph, we will cover five important subjects related to the mining of user interests from social media: (1) the foundations of social user interest modeling, such as information sources, various types of representation models and temporal features, (2) techniques that have been adopted or proposed for

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mining user interests, (3) different evaluation methodologies and benchmark datasets, (4) different applications that have been taking advantage of user interest mining from social media platforms, and (5) existing challenges, open research questions and opportunities for further work.

1

Introduction

Mining user interests from user behavioral data is critical for many applications, ranging from homophily analysis to recommender systems. Based on user interests, service providers such as advertisers can significantly reduce service delivery costs by offering the most relevant products (e.g., ads) to their customers. The challenge of accurately and efficiently identifying user interests has been the subject of increasing attention in the past several years (Zarrinkalam *et al.*, 2019a). Early approaches were based on explicit input from individuals about their own interests (Maron *et al.*, 1986). To avoid the extra burden of manually filling in and maintaining interest profiles, most methods in the past two decades have focused on the development of techniques that can automatically and unobtrusively determine users' interests based on user behavioral data from data sources such as browsing history, page visits, the links they click on, the searches they perform and the topics they interact with (Gasparetti, 2017; Holub and Bieliková, 2010; Li and Zhang, 2013).

With the emergence and growing popularity of social media such as blogging systems, wikis, social bookmarking, social networks and microblogging services, many users are extensively engaged in at least some of these applications to express their feelings and views about a wide variety of social events/topics as they happen in real time by

commenting, tagging, joining, sharing, liking, and publishing posts (Abel *et al.*, 2011b; Li *et al.*, 2008). According to Statista, a company which provides statistics and survey results, there were an estimated 3.6 billion people using social media in 2020, a number projected to increase to almost 4.41 billion in 2025.[1] This has made social media an exciting and unique source of information about users' interests.

For instance, when looking at Twitter data during the first week of March 2019, the rivalry between the two English Premier League soccer clubs, i.e., *Tottenham Hotspur* and *Arsenal*, is a topic that has attracted a lot of discussion and interest. The development of techniques that can automatically detect such topics and model users' interests towards them has the potential to improve the quality of applications that work on a user modeling basis, such as filtering twitter streams (Kapanipathi *et al.*, 2011), news recommendation (Abel *et al.*, 2011b) and retweet prediction (Feng and Wang, 2013), among others.

This monograph is a valuable resource for those who have familiarity with social media mining and basics of information retrieval (IR) techniques. Where appropriate, the monograph will not make any assumptions about the researchers' knowledge on more advanced techniques such as link prediction, matrix factorization, entity linking and knowledge graph-based reasoning, among others. As such, sufficient details about user interest modeling from social media will be provided as appropriate so that the content will be accessible and understandable to those who have fundamental understanding of IR principles. The monograph will only assume familiarity with topics included in an undergraduate IR course such as those covered in Manning *et al.* (2008).

The monograph is structured as follows.

- Section 1 provides the motivations of user interest modeling from social media and the scope and delimitation of this monograph by highlighting the difference between this monograph and other related review monographs and introducing some related research areas which are out of the scope of this monograph.

[1] https://www.statista.com/statistics/278414/number-of-worldwide-social-network-users/.

- Section 2 introduces the foundations of user interest modeling from social media such as information sources, representation units to represent each topic of interest and user interest profile, temporal aspects and cross-system user interest modeling.
- Section 3 describes user interest modeling approaches by focusing on three main perspectives: (1) explicit user interest detection, (2) implicit user interest mining, and (3) future user interest prediction.
- Section 4 describes the main evaluation methodologies which have been widely adopted in the literature followed by the existing benchmark datasets and evaluation metrics.
- Section 5 introduces different applications that have been taking advantage of user interest modeling from social media platforms to improve their services.
- Section 6 presents exciting open challenges, future directions and research questions in the state-of-the-art for modeling users' interests from social media.

1.1 Definitions

In this section, we provide concrete definitions of *social media* and *user interest modeling* as two key terms used in this monograph.

Social Media. The term *social media* has been defined in the literature in various ways by different communities such as communications, management, and computer science (Boyd and Ellison, 2007; Fuchs, 2014; Rohani and Hock, 2010). In this monograph, we follow the same definition provided by Obar and Wildman (2015), which synthesize the definitions presented in the literature by defining *social media* as a service that has the following four distinct commonalities:

- *Social media services are (currently) Web 2.0 Internet-based applications.* In Web 2.0 applications, users have become not only content consumers but also active producers.

- *User-generated content is the lifeblood of social media.* Social media services are not sustainable without user-generated content. For example, the videos that we upload to YouTube, the connections and posts that we generate on Facebook or Twitter play crucial roles in making those social media platforms live.

- *Individuals and groups create user-specific profiles for a site or application designed and maintained by a social media service.* User profile in a social media service provides a unique way of identifying each user which is important to enable social networks between users. A user profile here can refer to any information to uniquely identify a user such as a username, IP address, locations, contact information, etc.

- *Social media services facilitate the development of social networks online by connecting a profile with those of other individuals and/or groups.* For example, friends on Facebook, connections on LinkedIn and followers on Twitter and Instagram. Users are motivated to create their social networks in social media services for consuming content generated by their social networks or interact with them.

User Interest Modeling. Piao and Breslin (2018a) provided a general definition about user interest modeling and user profiles. We use a refined definition as follows.

The process of obtaining the user interest profile is called user interest modeling. A user interest profile is a data structure that represents the degree of interest of an individual user over a set of topics represented by words or concepts.

1.2 Related Review Papers

Despite the importance of user interest modeling from social media, there is a lack of an extensive review on this domain that covers the ideas, insights and applications of different approaches in user interest modeling from social media. Piao and Breslin (2018a) have reviewed studies in user interest modeling from microblogging websites such as Twitter by focusing on four dimensions: (1) data collection, (2) representation of

user interests, (3) construction and enhancement of user interest profiles, and (4) evaluation methodologies.

The authors in Piao and Breslin (2018a) have presented the foundations of user interest modeling from microblogging websites and overlooked other social media platforms (e.g., Facebook, Flickr and Pinterest). Further, they have not covered the potential applications of the extracted user interest models. Since we categorize different approaches proposed in the literature with respect to three main perspectives: (1) explicit user interest detection, (2) implicit user interest mining, and (3) future user interest prediction, this has set the stage for a more detailed presentation of the ideas and insights about different user interest modeling approaches. Moreover, in addition to providing the fundamental information that new researchers need for understanding this field, we extensively discuss the potential applications of the extracted user interest models and promising techniques which can be applied for future exploration in this field.

As another related review monograph, Safari *et al.* (2019) have recently reviewed different studies on user behavior mining from social media (UBMSM). They have provided different statistical and demographic information (e.g., venue types and publishers) about the publications in this domain. Further, based on the focus area of their studies, they have identified four main aspects which affect user behavior mining from social media: (1) user, (2) content, (3) network structure, and (4) information diffusion. For each aspect, multiple characteristics are defined and their impact and consequences on UBMSM are discussed. The authors have considered user interest modeling as one of the four characteristics of the user aspect and reviewed different related studies on this topic.

Therefore, in contrast to our work, the focus of the authors in Safari *et al.* (2019) is not directly on user interest modeling from social media and they have concentrated more on the effect of different characteristics and aspects of user behavior. As a result, they don't provide more in-depth analysis and discussion of the studies in this field. However, our monograph describes the specific techniques, evaluation strategies, benchmarks and challenges of user interest modeling from social media, in addition to concrete directions for future work. Consequently, we

believe that our review monograph is more insightful for a researcher interested in this specific field, i.e., user interest modeling from social media.

1.3 Related Research Areas

There are some research areas/topics which are related to user interest modeling from social media. Because each of these areas is a mature and active field of research and includes a rich line of studies in the literature, we will not cover them in detail and they are beyond the scope of this monograph. To provide a more in-depth analysis, we only review the studies that focus directly on user interest modeling from social media. In the following, some of the most important examples of these areas/topics, e.g., topic detection, personality prediction and latent user modeling from social media are introduced and their similarities and differences to the subject of this monograph are highlighted.

1.3.1 Topic/Event Detection from Social Media

There is already a well-established body of work in the literature that extracts topics/events from social media (Aiello *et al.*, 2013; Huang *et al.*, 2017a; Petkos *et al.*, 2014; Yan *et al.*, 2015). Applying topic modeling methods, such as LDA, over social posts is the main approach to extract topics from social media. However, since the majority of standard topic modeling methods are designed for regular documents such as news articles, they fail to identify the essential information of social posts which are short, noisy and informal. An intuitive solution to address this issue is first using a *pooling scheme* to aggregate the related social posts to a single document (e.g., posts published by a given user or in a given time interval) and then applying a standard topic modeling method on the resulting documents to extract topics from social posts. This allows for the discovery of better topics without modifying the existing topic modeling methods (Alvarez-Melis and Saveski, 2016; Mehrotra *et al.*, 2013; Rajani *et al.*, 2014).

To extract topics from social posts, instead of applying pooling scheme, some studies have applied some restrictions to simplify the

conventional topic models or developed novel topic models. For example, in Zhao *et al.* (2011), Twitter-LDA model has been proposed which assumes that a single tweet contains only one topic. Similarly, in Yan *et al.* (2015), the authors have extended the Biterm Topic Model (BTM) (Yan *et al.*, 2013), which models word pairs instead of words for effective topic modeling in short texts, by incorporating the burstiness of word pairs as prior knowledge in BTM for bursty topic modeling from social posts.

There is also another line of studies that extracts topics/events from social media by applying clustering methods over social posts or their features (Comito *et al.*, 2019a,b; Long *et al.*, 2011). As one of the earlier studies that focused on microblogging data, in Long *et al.* (2011), a *co-occurrence graph* is constructed by extracting topical words from daily posts. To extract events during a time period, the authors have applied a top-down hierarchical clustering algorithm over the co-occurrence graph.

The above studies can be considered as a related area to user interest modeling as they are applied in some studies to first extract active topics in social media and then the interest profile of users are modeled over the extracted topics (Arabzadeh *et al.*, 2018; Zarrinkalam *et al.*, 2018). In these studies, it is assumed that existing state-of-the-art techniques can be employed for extracting and modeling topics. Therefore, they are not engaged with proposing a new method for the identification of topics and only have focused on determining the degree of interest of users towards the topics once they are identified. Given this focus, we review the work related to the problem of user interest modeling from social media. Interested readers are encouraged to see Bhardwaj *et al.* (2019), Farzindar and Khreich (2015), Zarrinkalam and Bagheri (2016) for the state of the art on topic and event detection from social media.

1.3.2 Personality Prediction of Social Media Users

Predicting the personality of users from social media is another related research area to user interest modeling. In Kosinski *et al.* (2015), the authors have provided a comprehensive discussion about opportunities,

challenges and ethical aspects of social media involvement in psychological studies. As an example, they have studied users' profiles in social media in order to perform personality classification. Similarly, in Youyou *et al.* (2015), the authors have concluded that digital footprints created on top of user preferences (i.e., Facebook likes) are more accurate and valid than judgments made by social-cognitive experts. Therefore, there is already a well-established body of work in the literature that predicts users' personality traits from social media (Golbeck *et al.*, 2011; Souri *et al.*, 2018).

Most studies in this area have used the *Big Five* model (Halverson, 1994) as one of the most well-known measures for personality traits (the five personality traits according to *Big Five* model are openness, conscientiousness, extroversion, agreeableness and neuroticism). For example, in Souri *et al.* (2018), the authors have adopted the *Big Five* model to design a classifier which is able to automatically identify five classes of personality traits based on the users' social media profiles. In Golbeck *et al.* (2011), social behavior of a user is considered as a strong indicator to predict her personality. To model the behavior of a user in social media, the authors have developed a set of behavioral features based on the intensity and number of social interactions that the user has with her friends along a number of dimensions such as reciprocity and priority. They have analyzed these behavioral features along with a set of textual features and showed that behavioral features perform as well as textual features for predicting user personality.

Similar to user interest modeling approaches, the above studies try to model the users' behavior on social media by mainly analysing the textual content of users and their social relations. However, since these studies aim at extracting personality traits of users instead of extracting the users' interests, they dig more into the linguistic features. For example, to identify the personality of users, in many studies LIWC (Pennebaker *et al.*, 1999), which produces statistics on 81 different linguistic features of text, is utilized to study various emotional, cognitive, structural, and process components presented in the users' textual content. Interested readers about the state-of-the-art approaches on personality identification from social media are encouraged to see Kaushal and Patwardhan (2018).

1.3.3 Latent User Modeling from Social Media

There are plenty of studies that embed a user's information in social media such as the user's relations, textual content and demographic profile, into a latent low dimensional space (Benton *et al.*, 2016; Zhang *et al.*, 2017). These studies are usually tied to a specific task from which the model is learned and they represent user models by latent features which are not human readable.

For example, in Ding *et al.* (2017), the user's information on Facebook (e.g., *likes* and *status updates*) is embedded in order to build substance use detection systems to identify users who are at risk of substance use disorder. The authors have employed Doc2Vec (Le and Mikolov, 2014), which produces a dense low dimensional feature vector for a document, as one of their approaches to embed users. To learn user embeddings from social media posts, they introduced two methods: (1) User-D2V which treats all the posts published by each user as one document and trains a document vector to represent each user. (2) Post-D2V which learns a vector for each post and then aggregates all the post vectors from the same user to derive the user embedding.

As other examples, in Benton *et al.* (2016), the authors have proposed to embed different information of a user on Twitter (e.g., the user's posts, followers and friends) into a single embedding vector by applying a multiview approach. They have shown the effectiveness of their model on three different prediction tasks (i.e., user engagement prediction, friend recommendation and demographic characteristics inference). Word2Vec (Mikolov *et al.*, 2013) is one of the methods the authors have applied to represent each view of the user by simply averaging the word embeddings for all the words within that view (e.g., the user's posts). In Piao and Breslin (2018b), the latent representation of social posts and users on Twitter are learned for the application of tweet recommendation. Their proposed model employs Long Short-Term Memory neural networks (LSTMs) (Piao and Breslin, 2018b) for learning tweet embeddings, and calculates the degree of interest of a user to a tweet based on the similarity between the user and the tweet embeddings as well as the similarity between the user and tweet's publisher embeddings.

In this monograph, our focus is on reviewing the user interest modeling approaches that identify the degree of interest of a user over a set of topics each of which are represented by words or concepts. In other words, we do not review user modeling approaches that result in latent user models represented by a vector of numbers which are not human readable. A recent survey about social media-based user embedding can be found in Pan and Ding (2019).

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