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News Recommendation Systems - Accomplishments, Challenges & Future Directions

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ABSTRACT News publishers have decreased disseminating news through conventional newspapers and have migrated to the use of digital means like websites and purpose-built mobile applications. It is observed that news recommendation systems can automatically process lengthy articles and identify similar articles for readers considering predefined criteria. The objectives of the current work are to identify and classify the challenges in news recommendation domain, to identify state-of-the-art approaches and classify on the application domain, to identify datasets used for evaluation and their sources, the evaluation approaches used and to highlight the challenges explicitly addressed. The literature is thoroughly studied over the time span of 2001-2019 and shortlisted 81 related studies, broadly classified into six categories and discussed. The analysis showed that 60% of news recommendation system adopted a hybrid approach, 66% studies little talk about datasets, and addresses a few challenges from a long list of challenges in the news domain. This article is the first in the field to draw a comprehensive big picture of news recommendation and explore different dimensions covered in the studies. The last section presents the future research opportunities that lead to improving the recommendation of news articles in the news domain.

INDEX TERMS Recommendations, news recommendations, literature review, recommendation techniques, news recommendation overview.

I. INTRODUCTION

The advancement in technologies like high-speed internet access on handheld devices and customized software applications for news is beneficial for news readers as they provide very easy access to the information published on multiple sources. It is the human inability to browse through such a vast information space for related news stories. The number of news releases has grown rapidly and for one individual, it is cumbersome to browse through all online news resources for relevant news articles. Search engines help users up-to some extent in searching through the vast information collections available online and the recommendation systems have emerged to address different challenges and provide users with the information which matches their needs either by their preferences or by content similarity. Each online news publisher tries to handle its news and use some mechanisms to recommend similar news to their readers.

The recommendation of news articles is a hard task because of a highly dynamic environment, which leads several challenges, e.g. frequent changes in the set of news articles, set of users, rapid changes in user's preferences, etc. Therefore, recommendation algorithms must be able to process continuous incoming news streams in real-time. The complex requirements of news recommendations based on some relevancy among news articles that best fulfill the user's requirements lead to many rich research scenarios and make it more interesting.

In this paper, the focus is to find out the state-of-the-art research in the field of news recommendation and its related concepts. We designed a few research questions related to different aspects of the news recommendation domain and

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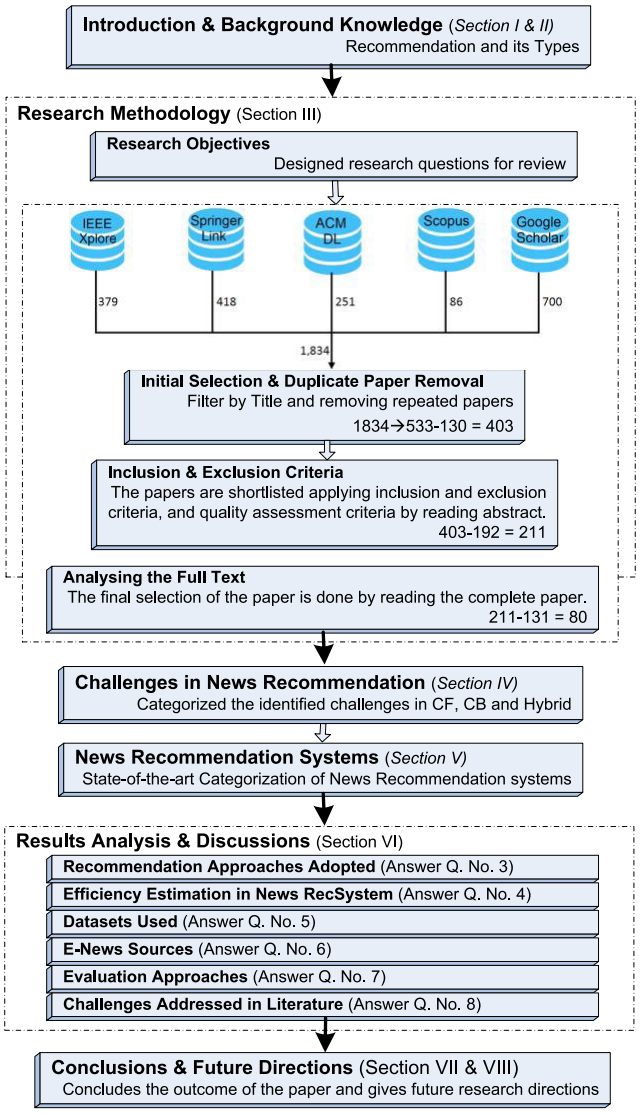

FIGURE 1. Paper flow and its different sections with brief description.

tried to answer by comprehensively studying the literature from 2006-19 over a span of 14 years. The paper and its different sections are summarized in Figure 1.

The remaining paper is organized as section II briefly discusses the broad topic of recommendation systems and common approaches for the recommendation. The section III presents the research objectives, data collection with search strategy, inclusion criteria, quality assessment criteria and other relevant details. Section IV comprehensively discusses challenges specific to news recommendation. Section V presents eighty different studies, categorized in six categories sub-fields involved. The analysis and results are presented in section VI. Finally (section VIII), presents some guidelines that lead to future research.

II. RECOMMENDATION SYSTEMS

An application that helps to predict items based on the user responses to other options of items set or a meaningful recommendation to a collection of users for product or items that may interest them is a recommendation system [21], [63], [84]. The "recommendation systems help users to find information and make decisions where they lack the required knowledge to judge a particular product. Also, the information dataset available can be huge and recommendation systems help in filtering this data according to users needs" [3]. For example, suggesting books on Amazon, movies on Netflix, news on online newspaper website using recommender systems. However, observing the examples bring the problem into the focus for recommender systems and researchers.

For example; suggesting news articles to the online newsreader based on the similarity of a news article with the news they are reading or proposing news articles based on the interest of newsreader subjected from their previous readings and the feedback of the reader. In the first scenario, the recommendation is made on the bases of the similarity estimated from the news article's features. Secondly, the recommendation of further reading is made by observing the reader interest and characteristics.

Today's interactive and adaptive web demands recommendation systems as a key feature to best manage the subjects, whether they are browsing through research articles at scientist's portals, i.e. Mendeley, news articles at online newspaper website, books at Amazon, movie files at IMDb, peoples at social networks, i.e. twitter, music file at Last.fm or online products at *daraz.pk*, etc. In short, all e-commerce websites of various natures accustomed to a personalized data consumption experience of their users [98]. A recommendation system is an active research area, which has dedicated conferences, journals, workshops, and intersecting a number of disciplines like human-computer interaction, machine learning, data mining, information retrieval and statistics [84].

A recommendation system is abstractly considered as the integration of three main components, i.e. data collection, a recommender engine and user interface [3]. The recommendation engine can be designed by combining three subcomponents, i.e. a recommendation model or algorithm, post-processing and online or offline module.[1] Too many approaches adopted for recommendation system that can be broadly categorized into the following three categories and subcategories.

A. COLLABORATIVE FILTERING APPROACH

The term collaborative filtering technique was initially introduced in the first commercial recommendation system, named as Tapestry [31], which was designed for documents recommendation to a group of users drawn from a newsgroup. CF is a class of recommender systems based on user feedback in the form of liked, disliked, ratings about items, etc. CF approach predicts and recommends items or products to users (or subset of users) having similar tastes, using predictive models based on the past ratings or likeness behavior of all the users [6], [32], [33], [78], [84], [91]. CF is a

[1] https://buildingrecommenders.wordpress.com/

useful approach as compare to content-based approach where content analysis is difficult, e.g. multimedia files. A number of sub-categories of CF approach in recommendation systems [84] exist.

- Neighborhood-based Collaborative Filtering (technique based on active users and weighted combination of their ratings) [84].
- Item-based Collaborative Filtering (technique based on item-to-item CF for fast recommendation as compare to neighborhood technique) [74], [101].
- Model-based Collaborative Filtering (technique based on estimation of parameters of statistical models of user ratings) [59].
- Memory-Based Collaborative Filtering (technique based on user-item weighted correlation between two users or items to predict preferences) [101].
  - A number of similarity computation techniques is used for memory-based CF, e.g. Correlation, Cosine, Conditional probability, Pearson Correlation, Weighted Sum, Weighted average, User-based and item-based Top-N measures, etc [100], [108].
  - A number of machine learning and data mining algorithms are used for intelligent predictions, e.g. NB-ELR, TAN-ELR, Bayesian's, clustering, Regression, and MDP based algorithms, etc [36], [104], [108].

B. CONTENT-BASED APPROACH

Contents-based filtering is a prevalent approach in Information Retrieval comparatively because the main entities to retrieve from web repositories are the textual contents or multimedia contents that best suited the user's query. In recommendation systems, it provides recommendations of an item by comparing features [84]. The focus of content-based recommendation systems is on the properties of the items, where the similarity among items are determined by comparing the properties of the items [101]. In content-based filtering approach, users or items are considered as atomic units and better-personalized recommendation is being made knowing more about user or item. For example, demographic information of a user or item features like stars, director or genre of a movie [6], [78], [83], [91].

The conventional TF-IDF vector-space model has commonly adopted technique for content-based filtering approach used to select a set of candidate items. TF-IDF algorithms apply to different dimensions of an article by selecting contents and for calculating similarity among them [3], [18]. For example, title, summary, freshness, keywords or entities from a set of candidate articles, etc.

Each approach has its own advantages and disadvantages in different scenarios. To overcome or minimized these limitations, hybrid approaches are adopted.

C. HYBRID APPROACH

To leverage the strengths of both the collaborative filtering approach and content-based filtering approach, a number of hybrid approaches have been introduced. A simple way is combining the recommendations of both the approaches into one single final recommendation, i.e. using adapted weighted average [84]. To overcome the limitations faced by both collaborative and content-based approaches, the hybrid approach produced more accurate recommendations than individual methods [3], [6], [7], [32], [78].

"Content-boosted Collaborative Filtering" is a generic framework, where content-based recommendations are applied to convert a sparse user rating's matrix into a full rating's matrix, and then a CF method is used to provide recommendations using Naıve Bayes classifier [83]. Improved results demonstrated by using TANELR content-predictor and unweighted Pearson collaborative filtering [107]. "Extended Hofmann's aspect model" is a three-way data occurrence model, which integrate data concurrence about items, users and item's contents [102]. Some of the hybrid approaches use probabilistic framework by combining both collaborative data with content for a recommendation.

III. RESEARCH METHODOLOGY

A. RESEARCH OBJECTIVES

A lot of work has been done in the last decade about news recommendations using different publishing platforms. To formalize news domain and approaches adopted, datasets used, challenges encountered, measures applied, etc. the study pursued and the literature is keenly evaluated. To quantify the objectives, quantitative analysis was conducted in the news recommendation domain and designed the following questions.

1) What are the different challenges facing by the news recommendations domain?
2) How to classify the news recommendations systems based on a specific domain?
3) Up to what extent the common recommendation approaches (CB, CF or Hybrid) are adopted?
4) How do authors provide information about the Efficiency of algorithms or techniques applied?
5) Which datasets are used? Do the papers provide sufficient information about the dataset?
6) What are the e-news sources used for the news recommendation studies?
7) How the evaluation is conducted for the news recommendation studies?
8) Which challenges are explicitly tackled?

B. DATA COLLECTION

To achieve the designed objectives/questions of the study, we comprehensively reviewed the literature and used a systematic literature review as the primary method for data collection [49], [88]. We identified and evaluated the relevant published research work to analyze the designed research questions following SLR (Systematic Literature Review) guidelines from [49] and [57] by our research team took part in all phases of the study. To avoid the personal biases

TABLE 1. Objectives against research questions.

Q No.	Intended Objectives	Address in
1	The objective is to identify all the challenges encountered by the news recommendation domain and classify the challenges into main approaches of recommendation.	Section IV
2	The objective is to classify the news recommendation systems based on the application domain from a broader perspective, e.g. Social Media and News Recommendation, which specify the role of social media or social networks in news recommendation.	Section V
3	The objective is to see how the common recommendation approaches are adopted in news recommendation studies and its trend.	Section VI-A
4	To identify, how the efficiency is estimated by the approaches adopted for news recommendation systems.	Section VI-B
5	To identify the baseline datasets used for evaluation and how they explain the datasets used.	Section VI-C
6	To analyze the news sources of datasets used for evaluation.	Section VI-D
7	To specify the conduction of evaluation processes and approaches to find the worth of different studies for news recommendations.	Section VI-E
8	The aim is to highlight the challenges explicitly addressed and the challenges did not address at all.	Section VI-F

TABLE 2. Search terms.

Feature	Search Terms / Queries
Multi-Word Queries without Operators	Recommendation Systems, Recommendation Techniques, Recommendation Approaches, News Recommendation, Recommendation Challenges, problems, issues, limitations, News Recommendation Challenges, Content-based Approach, Collaborative Filtering Approach, News Recommendation in different domains
Multi-Word Queries with Operators	Recommendation Challenges OR problems OR issues OR limitations, News Recommendation Challenges OR problems OR issues OR limitations, News AND Recommendation, News AND Recommendation AND (Techniques OR Approaches OR Methods), News AND Recommendation AND (Challenges OR problems OR issues OR limitations OR Complications)

and improve the quality of the literature review process, the inter-rater tests were conducted at both the initial and final paper selection phases. and followed the following steps;

1) SEARCH STRATEGY

The suitable search terms are selected to make sure that no relevant research article is missed in different known research databases and search engines. We found the following terms and synonyms to be relevant to the theme of the study, to achieve the objectives. The terms used for the search strategy is presented in TABLE 2.

The Boolean operators are used to combine the major search terms and constructed the search terms after validating them via related research papers as shown in TABLE 2.

For this study, known academic databases are used to retrieve the relevant research articles published during 2006-2019, as listed below;

- IEEE Xplore
- Springer Link
- ACM Digital Library
- Scopus - Elsevier
- Google Scholar

As these databases have considerably different search criteria and capability, we accordingly adopted our search terms and queries.

2) INCLUSION & EXCLUSION CRITERIA

In the study, we applied the following inclusion criteria for studies related to different aspects in news recommendations;

- Manuscripts from different platforms are included during 2006-2019, such as Conference Proceedings, Magazines, and Journals.
- Manuscripts focused on News recommendations, challenges in news recommendations, approaches, datasets (E-news sources) and news recommendation in different application domains and other related aspects.
- Thesis, such as Graduation, Masters and Doctoral theses.

We applied the following exclusion criteria:

- Manuscripts published in other languages than English.
- Manuscripts published in other domains of knowledge, such as Chemical Engineering.
- Technical reports and white papers.
- Books, such as Textbooks, both printed, and e-forms.

3) QUALITY ASSESSMENT CRITERIA

The initial selection of any paper to be included in the relevant paper list is set. We set four quality assessment criteria for the paper, and a paper needs to achieve a score of 1 for initial selection and minimum 3 for the final selection as shown in TABLE 3.

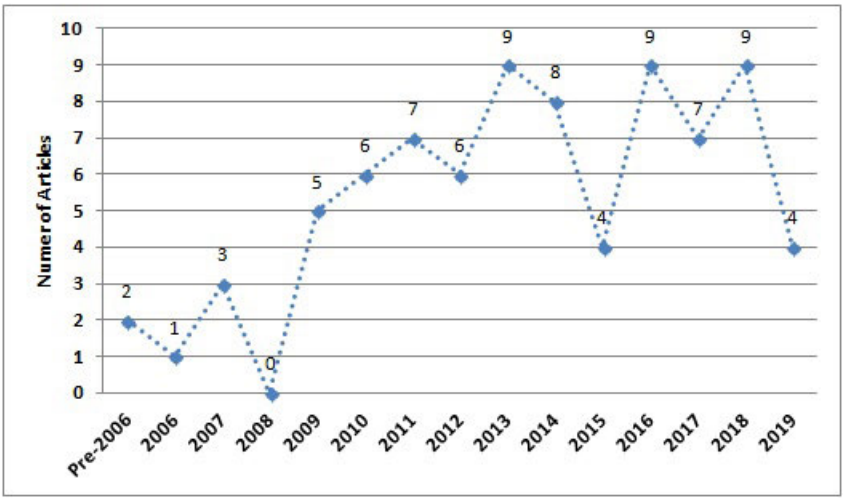

FIGURE 2. Year-wise published paper distribution.

TABLE 3. Quality assessment criteria.

Quality Criteria	Score
Does the study discuss recommendation systems?	Yes = 1, No = 0
Does the study discuss any aspect of news recommendation systems?	Yes = 1, No = 0
Does the study discuss the results and findings?	Yes = 1, No = 0
Does the study discuss challenges in the news recommendation domain?	Yes = 1, No = 0
Is the study is adequately referenced?	Yes = 1, No = 0

4) SELECTION, EXTRACTION AND ANALYZING THE DATA

The selection of a paper is done in two steps, such as initial selection and final selection. The initial selection is performed in two steps, i.e. first, based on reading the title of the paper and secondly, shortlisting the paper by reading the abstract of the paper and removed all the irrelevant papers which do not qualify the quality assessment criterion. The final selection based on reading the complete paper and quality assessment criteria. The total number of papers retrieved from different step filtration is given in TABLE 4 based on search terms presented in TABLE 2.

For Google Scholar, we considered only the top 700 retrieved results and two-papers are the joint publications of IEEE and ACM. Finally, 81 papers from different publishing platforms are selected based on quality assessment criteria span over a period of 14 years, i.e. 2006-19. To avoid the researcher's selection bias, inter-rater reliability test is conducted, where two researchers are asked to randomly choose ten publications each from the total results' list and carried out the initial selection process and compared. Year-wise distribution is shown in Figure 2.

Most of the research papers for news recommendation systems and challenges included in the study are retrieved using forward search and backward search using Google Scholar. Other known publishers like, ACM, Elsevier, Springer, IEEE, IGI, PeerJ press etc., are searched for relevant papers. Publisher distribution is presented in Table 5.

IV. CHALLENGES IN NEWS RECOMMENDATION DOMAIN

At a first look, it seems easy to build a recommender system for news recommendations, in fact, it's not. Finding the proper news article to be recommended is a tactical task based on news similarity among news articles or based on user preferences and interests. To build a good recommended system for news domain needs to tackle a number of challenges that intimate opportunities for further research. In this section the focalising not only to discuss generic challenges but specific news challenges of recommendation systems and categorized it in three common approaches, i.e. Collaborative Filtering (11 challenges), Content-Based (06 challenges), and Hybrid (04 challenges).

A. COLLABORATIVE FILTERING APPROACH CHALLENGES

1) Cold-start Problem
The cold-start problem is one of the major problems in all recommendation systems based on collaborative filtering. The problem raises when a new user joins the system and doesn't have any clicks, there is no data about the user to recommend items [38], [84], [90], [102]. The problem is an obvious case when the system is initiated for use or when the system has high item-to-user ratio and can be reduced by additional information of the domain [83], [107]. The cold-start problem becomes more intensive in the news domain because new users' visit, after an event has occurred or users who occasionally visit news sites based on the expected news articles to be published online. It is also referred as first rater, ramp up or early rater problem [87].
2) Explicit User Feedback
Without explicit news reader feedback, it's difficult to be observed or understand the reader satisfaction

TABLE 4. Search results.

Databases	Total Results	Filter by Title		Filter by Abstract	Filter by Text
		Selected Papers	Repeated Papers		
IEEE Xplore	379	73	11	23	13-02
Springer Link	418	66	06	19	06
ACM Digital Library	251	113	05	70	34-02
Scopus (Elsevier)	86	42	0	16	08
Google Scholar	700	239	108	83	24
Total	**1,834**	**533**	**130**	**211**	**81**

TABLE 5. Reviewed paper's publisher distribution.

Publisher	Genre	Papers	AID
IEEE Xplore	Journal	03	[A15][A63][A73]
	Conference	06	[A07][A16][A49][A61][A63][A77]
Springer Link	Journal	02	[A21][A25]
	Conference	04	[A11][A17][A18][A44]
ACM Digital Library	Conference	32	[A01][A02][A04][A06][A09][A12][A13][A19][A20][A22][A23] [A26][A27][A32][A33][A35][A38][A41][A47][A48][A50][A54] [A57][A58][A59][A64][A66][A68][A69][A70][A71][A74]
ACM/IEEE	Conference	02	[A24][A31]
Scopus - Elsevier	Journal	07	[A05][A14][A30][A39][A46][A60][A76][A81]
PeerJ	Journal	01	[A52]
CLEF	Conference	05	[A43][A51][A53][A63][A67]
Others	Thesis	02	[A34][A37]
	Journal	09	[A08][A10][A28][A29][A40][A42][A45][A55][A78]
	Conferences	07	[A03][A36][A56][A72][A75][A79][A80]

about the article, whether a news reader liked the article or not [22]. The explicit feedback of a news reader can play a vital rule in precise recommendations of that news article to the same news readers by using collaborative or content-based filtering techniques. The lack of interest of user interaction with the system makes it hard to get explicit feedback, so that the system should be able to conceive implicit feedback from the news readers for effective recommendations and the privacy of the reader should keep intact [18], [90]. Implicit & Explicit user feedback is difficult to get about the news, read by the users because the user may read many news stories and not willing to provide feedback so implicit feedback may help to recommend other news, e.g. clicks or time spent reading a complete story.

3) Continuous Changes in User Interests
In all types of user-based recommendations, predicting user's future interest is a key challenge and highly dynamic in the news domain. The user's interests could be changed with the events happening [65], e.g. a news reader may be interested to read articles about a football match in world cup season and the same news reader may be interested in news about CPEC development project. Generally, a news reader reads news not because they are interested in but to find it important [90]. For example, if a user reads about Panama papers and read about the politicians involved, this does not indicate the interest of that person in the politics.

4) Changing User Interest due to Topic Divergence
One of the fundamental challenges in adaptive news recommendation is topic divergence, i.e. during discussion the gist changes from the original news for the users followed by other news readers. As the discussion continuous, the concerns or intension of the active user's may change in the form of votes and comments. If the recommendation is based on the original post, it can be hard to benefit the users of the potentially changing interests [69].

5) User Modeling or Profiling
For specific personal recommendation of news articles, a comprehensive user profile is required to be maintained, which encompasses user preferences and interest. User profiling is mandatory part of any collaborative recommender systems [90]. A number of profiles based recommender system is constructed e.g. [16], [22], [99], [106], etc.

6) User's Privacy Problems
For specific personal recommendation of news articles, a comprehensive user profile is needed to be maintained by knowing their preferences, likes, dislikes, past interactions with the system, interests and even the relationships with other users, though this relation may cause some privacy issues [90], [113]. Taking care of user privacy, knowing everything about users is a huge challenge task.

7) Gray Sheep Problem
As collaborative filtering techniques recommend item based on the common interests of a user's group,

therefore, a recommender system cannot recommend proper items to an unknown user, i.e. when a user whose preferences do not consistently match with the preferences of any group of users with specified preferences [108]. Typically, grey sheep problem handled by recommending the items choose randomly or select newest or popular items. The grey sheep problem decreases when the number of users increases [40], [90].

8) The Context-Dependent Relevance of Items
User preferences often highly depend upon the context and the specific domain. The recommendation of items could be on the bases of the context of user previous read news articles for accurate and related news articles to the news readers [96].
9) Unpredictable Behavior for the Same Items
Recommendations of audio or video files are hard to determine based on the user preferences and past interactions. Because these preferences are directly related to the mood of the user and may change.
10) Unwillingness of Users to Register
One of the challenging factors in recommender systems is the lack of rich browsing history of users because the users are not compelled to register and hence, it is difficult to maintain persistent user's profiles [18]. In the news domain, the news readers visit a specific news website occasionally or visit many websites for comprehensive knowledge, so generally not bother to register on a single newspaper website.
11) Using Shared Devices
The internet can be accessed through multiple devices, so a news reader can use different devices for reading news articles or many users can use a single device. This phenomena make it more complicated and difficult to reliably track user's browsing history [18], [55] or profile information.

B. CONTENT-BASED APPROACH CHALLENGES

1) Recency
The biggest challenge in news recommendation is recency of news articles to be recommended. The news readers prefer to read about latest happening around. Therefore, it is a huge challenge to recommend the most relevant news articles and fresh news instead of outdated news articles. The fresh news articles are more important than old ones, in some cases the old or previous news may be required to be presented to the news reader based on the context of current happening to get thorough information and understanding about the subject [65], [90].
2) Continuous Changes in News Items Set
The news generation in the digital environment is no longer periodic or linear process with fixed single output like the printed newspaper. The news are instantly generated and updated in continuous fashion. On average, about 150 news articles are published online by a renowned newspaper [51]. One of the main challenges in news domain is the continuous change in news article set [96].
3) Unstructured Content
Content-based recommender systems need to analyze content information of the items. It's hard to analyze unstructured contents than structured contends. For better recommendation of news articles should be in structured and machine readable form [90], [99].
4) Response Time
Response time is one of the main challenges when developing a recommender system for news domain. Recommendation from such a huge collection may cause delay in response time against user queries and the precise recommendation may take long than expected [96].
5) News Recommendation from Multiple Sources
News readers prefer to read news articles from multiple sources to get comprehensive knowledge about an event happened or latest development about a news story or different perceptions and point views. Finding relevant news articles published in another source about the same event without proper recommendations by a system is a difficult task.
6) Cross Lingual News Recommendations
Recommendations systems are generally developed to present news articles published in single language and from one source. Recommending multi lingual news articles from multiple sources and deploying effective similarity techniques for proper recommendation is a challenging task e.g. news article published in English recommend same news published in Urdu language for better understandings from multiple sources.

C. HYBRID APPROACH CHALLENGES

1) Data Sparsity
In collaborative filtering, the matrices use for user ratings. These matrices can be sparsed when there are not enough entries of ratings by users. The sparsity of the matrix increases as number of items or users increases, sparser when tilted by users or items (item-user matrix) [90]. As the sparsity is increased when more items are added to the system so in the news domain this problem will be more prominent, for example, new news published online in continuous fashion and the number of news item increases rapidly. It is also referred in literature as Neighbor Transitivity problem [90], [108].
2) Scalability
Recommendation systems are expected to serve millions of users at a time [16]. Items need to be recommended precisely and efficiently from a huge collection. As compare to other domains, news domain is anticipated to be published thousands of news articles in an hour at different news sources. So such a dynamic environment deemed recommender systems

having real time capabilities like fast processing, scalable to the amount of data expected from different sources and independent of the underlying approach used [65], [90], [96].

3) Serendipity Problem (recommending same item again)
The recommendation of an item previously recommended from different or from same source is disliked by the users and is a major problem in content-based recommendation [26], but also a problem for collaborative filtering recommender systems [40]. For news articles in the news domain, a news may be written differently by different sources, recommended by recommendation system as a different news article and it is obvious that the users would not be happy to get the same or similar recommendations. It is also referred in literature as Synonymy (problem due to synonymy) [90], [108]. In contrast, a user may like to read a similar article because news readers read news online from multiple sources to get desired information in comprehensive information space be an advantage rather than disadvantage.

4) Fraud
The recommender systems are being progressively adopted by commercial websites because they can be used to significantly improve the profitability of venders unscrupulously. The recommender systems are used to rank their own product highly (push attack) and can show low ratings of the competitor's products (nuke attacks) and other types of attacks, e.g. shilling attacks [122] or profile injection attacks [87], etc. For high ratings of their own products, they create dummy profiles, which are difficult to identify.

V. NEWS RECOMMENDATION SYSTEMS

The World Wide Web is a platform that provide access to online published news articles to the news readers from millions of news sources around the world. They are encouraged to express themselves in the form of views, reviews, opinions, ratings, comments, sharing this information by tagging, sharing and contributing new information [19]. The accessibility and availability of these facilities create a huge pool of information through news. Recommendations of relevant information or news by filtering or summarization of web news and present concise news contents to the targeted news readers, attracts researchers to find out new methods of linking and recommending related news articles precisely. Recommendation systems help to suggest the most relevant items or information from a huge collection of items or data in different application domains at the internet with minimal efforts of the user. News recommendation systems are specific application domain, where the objective is to recommend the most relevant news articles to the news reader based on some recommendation approaches. News recommendations offer specific challenges (technical point of view and general approach related challenges) as compared to other application domains [90]. For example, news recommendation system entails challenges like tight response time, dynamic environment and continuously changing collection of news articles or users, heavy load peaks at rush hours, etc [113]. A lot of work has been done in news recommendations, especially in last decade and can be categorized as follows;

A. SOCIAL MEDIA AND NEWS RECOMMENDATION

The news recommendation systems suffer through two main collaborative filtering problems, i.e. Data sparsity and cold-start problem. online news readers read limited news article and hence cause a very sparse access matrix. The dynamic nature of news (new news items) evolves the news group (new news readers) and hence causes the cold-start problem. For new users in recommendation systems, researchers turn to get information about new users using the social network [103]. The social network websites (Twitter, Google+, Facebook, etc.) can be incorporated into news recommendation considering different aspects. News recommendation systems can be broadly classified under two types based on the approach adapted that take advantages of social networking sites support news recommendations to news readers [45]. Different personalized news recommendation systems adopted social networking sites for community description [1], topic evolving on a forum [69], using mining techniques for constructing user profile [34] and more sophisticated techniques like personalization based on location, Twitter and Facebook profiling [48] etc., which help in news personalization.

Facebook online news recommendation system [1] is proposed to provide daily newsletters for communities on Facebook based on community description. The system is evaluated for utility, accuracy, and scope of application; on a set of 22 students from University of Illinois by presenting the proposed system on the regular basis. The system is scalable and sustainable for large community and users found the application useful and efficient for social networking websites.

A news recommendation approach based on combining two features, i.e. news article reader comments that refine recommendation of news and evolving topic, for forum-based social media is introduced [69]. Topic evolution is considered to handle topic divergence during discussion in adaptive news recommender systems, in social media it can be reflected by the user's comments. The system needs to build topic profile for each news article along with news reader's comments to retrieve relevant news articles. The adaptive news recommendation system is evaluation over a synthetic dataset collected from two news portals, i.e. Digg and Reuter's news. The experiments were carried out on 45 news articles selected randomly from Digg and the recommended the news articles selected from the news pool of Reuters. The approach is further evaluated on TREC dataset using three retrieval engines, i.e. Lucence, Lndri and Okapi.

PEemiSE is a personalized news recommender framework based on implicit social experts [72]. The system is employed by the combination of information diffusion model with

collaborative filtering and content-based models. The news dataset used in PRemiSE is created from many different known news websites [65]. The dataset of news articles contain news title, news contents, publication time, etc. and user details like news articles accessed, accessed time and user's anonymity, etc. The PRemiSE framework is enhanced and news personalization is improved considering implicit social experts by extracting opinions of potentially influencing users from their implicit feedbacks [71]. PRemiSE [71] is the extended form of previous study of the system PRemiSE [72], and it is different by three points. 1) A matrix manipulation method is presented despite of the sparse binary user-item matrix, 2) Implemented by large-scale dataset and utilized a four-step social network construction framework, and 3) The experiments are done on large-scale, real news recommendation datasets and the parameters are carefully justified. The PRemiSE is evaluated and comparisons are conducted with state-of-the-art techniques. To handle the cold-start problem experimental results presented that showed effectiveness and efficacy of the system. Two datasets are used that are distributed in training set and test sets from project SCENE [65].

A personalized news recommendation system using latent relationship of news article and microblog is presented in [34]. The news organization method is using a hybrid classification and clustering to predict by constructing user profile. The framework work in four modules as, the classification and clustering module that categorizes news based on classical classification method and named entity in 23 categories. For the collection of microblog messages their microblog SINA is used which contained 280, 737 news articles, 124, 301 messages from 5, 127 users with users who tweet or retweet less than 10 messages.

A Signal-based news personalization and recommendation approach based on oral dynamics of active user's interest capture from twitter timeline. The system is trained by using Bag-of-Signal model (discrete wavelet transformation technique) to use profile similarity and recommend news articles based on informative entities and defined functions [8].

TWITTER-BASED NEWS RECOMMENDATIONS

Twitter is a free social networking micro blogging service that plays a vital role in constructing user profile for personalized news recommendation and to avoid many challenges of collaborative filtering approach [45], especially cold-start problem. The following are the studies conducted to merge the social networking site Twitter with news domain for recommendation and personalization.

Buzzer is a real-time micro-blogging news recommendation using Twitter, recommending topical news stories from user's favorite RSS feeds [94]. The system recommends news by harnessing Twitter information to identify emerging topics of user's interest and combines it against recent coverage in RSS feed. The Buzzer system has potential to act as collaborative news recommender system like new RSS feeds based on the relevant people to follow twitter. Buzzer [93] enhanced from basic prototype [94] to rank RSS news stories to a user by mining terms that represent trends from public Twitter timeline and the timeline of the user's social graph, i.e. friends and followers.

A hybrid personalized news recommendation system with the help of micro-blogging service such as ''Twitter'' is presented by [44]. The news articles are recommended and ranked based upon two things, i.e. the popularity of news articles discovered with the help of tweets from public timeline and based upon the user profile preferences and interests. The system is evaluated by asking the users to rank the news articles. The experiments were done using Sports, business, crime, technology, politics, health, crime, and 40 news articles from each category from BBC and CNN by conducting 27 volunteer test subjects.

A personalized news recommendation system adopted hybrid approach by combining two things, i.e. 1) the popularity of news article on micro-blog service Twitter from the public timeline, and 2) construct user profile based upon their interests and preferences [45]. The proposed hybrid approach is evaluated on collected RSS articles from either CNN or BBC by filtering the non-news contents, e.g. html tags, number, etc. while preserving textual contents stored in file system after applying Lucene indexer. The Tweet Collector (Twitter streaming API) collects the tweets from the Twitter's public timeline to store in JSON format after filtering the non-tweet contents and identified the popularity of news articles using cosine similarity (article, tweet).

The *ImmRec* (immersive recommendation) is a hybrid personalized news and local event recommendation approach for handling the cold-start problems. The ImmRec is a topic model technique that uses multiple digital traces of the users to recommend based on 33-participant's tweets, facebook's comments, and emails of active users from medium.com and meetup.com [39].

The *Learning-to-Rank Hashtagger system* is a streaming news recommendation system that is introduced to recommend news by incorporating twitter hashtags. The recommendation helps to improve retrieval, track stories and summarize news content to the twitter communities and the proposed approach is evaluated both online and offline for an online news publisher [105].

B. SEMANTIC-BASED NEWS RECOMMENDATION

To manage overloaded information space of news domain, the contextual factors may play an important role in recommendations of news article that best match the user preferences. Semantically rich domain knowledge models incorporation might produce good results for news recommendation beyond the traditional recommendation techniques. Semantic-based systems like contextualization [9], [91], context-dependent relevance [10], domain ontology [41] and other related studies briefly discussed below;

News@hand is a semantic contextualizes news recommendation system [9]. News@hand presents several numbers of recommendations, e.g. driven by concept-based query, based

on user's profile, similar group of users, etc. The relevance of the news articles in the current user context for semantic profile is directing by two colored bars, semantic annotation and global user's ratings. A total of 744 ontology classes having about 121 thousand instances were populated with about 137 thousand entries from Wikipedia. The News@hand system is analytical evaluated by 16 users (graduate students and lecturers) to investigate both the models (personalized model and semantic contextualize model) by measuring precision of the recommendations. A three-folded knowledge model [10] has introduced, where interrelated semantic concepts are incorporated with the user and item space by *extended News@hand framework* to address cold-start, data sparsity and context-dependent relevance problems. They contributed an extended semantic description of user preferences and item contents via ontological relations.

Athena is an ontology-based news recommendation system for Herme's framework [23] (semantic-based approach for retrieving news items directly or indirectly related to concepts of interests from domain ontology) [41]. Athena recommends news articles based on observing user behaviors using the domain ontology-based method. The news is recommended by comparing term-based recommender and various semantic-based recommendation algorithms.

Semantic-based new recommendation system based on concepts and their semantic similarity is presented by [11]. They deployed two methods, first, Synset Frequency (Inverse Document Frequency (SF-IDF) uses WordNet synonym set rather than term frequencies and second, Semantic Similarity (SS) for creating five measures to compete similarity among news articles. It is a hybrid approach, in SS the WordNet synsets from the unread news items compared with the WordNet synsets from all the read news items in the user profile.

News Explorer is a news and data exploration browser for recommending news articles to the end users, especially for journalists [42]. The News Explorer is a proof-of-concept that illustrates that it is indeed possible to create an immersive, network-based, data-exploration browser, optimized for touch-based devices. The News explorer is evaluated on a set of 863 news articles collected from the newspaper Guardian over a period of seven days using Alchemy API (is a semantic tagging service that detects and disambiguates Named Entities from textual information).

News recommendation model based on the emotion of news and how the user feels about the news article is introduced by [91]. The model is used to recommend news that has positive impact on user's mood, utilizing both emotion and user's preferences. The nearest approach that is adopted is context-aware technique using for more personalized news recommendation using short or long-term user's preferences. The emotion is extracted from news title and root of the verb to use for estimating the emotion of news using the proposed technique and vector space method (Until now, the emotion can be extracted from news by considering the user's opinion). It modeled short-term (dynamic interests change constantly) and long-term (more stable and consistent preferences) user's preferences using the content-based approach.

C. MOBILE-BASED NEWS RECOMMENDATION

Reading news articles were a niche use of smartphones for users reading news on the go [118]. In US, two in every three mobile device users access news articles daily [85]. Access to news using mobile devices perfectly complemented the nature of 24/7 online news stream, especially breaking news. Combining mobile devices with personalized news recommendation techniques would enhance the capabilities of people finds news relevant to them. News recommendation via mobile opens different aspects to merge both these technologies, e.g. recommending news articles based on current trends to mobile users [3], location, preferences based recommendations [110], news representation, interaction [15] etc.

MONERS is a mobile news recommendation system, which integrates two things [62]. First, news article attributes (recency and importance), second, user preferences (user profile, reading patterns and changes in user interests) with respect to news contents and category. The MONERS system is evaluated and the experiments being done on registered members of a Korean mobile service provider's intelligent wireless service over the user log collected for six months.

EagleRadio is a news recommendation system for phonic web and pervasive access over mobile networks, based on hybrid collaborative filtering approach, i.e. combine two users profiling (user listening history) and neighborhood-based (user's with similar taste and preferences) approaches [13]. The two proposed algorithms, i.e. NNR and NNMC, are evaluated by news articles dataset included from the SOHU RSS (Really Simple Syndication) content center about ten categories and sub-categories.

NewsReader is an android based application used to recommend news articles based upon two things, i.e. user-reading habits recorded over a period of time and the news articles based on current trends [3]. The collection is populated with news articles collected from Yahoo, CNN and TOI. The NewsReader is evaluated by android application, which has simple interface displaying the news articles of various categories. Recommend news articles based on user preferences and the click behavior of the users group carried similar interest.

A multi-perspective transparent approach for news recommendations on mobile devices is presented in [110]. It is a hybrid multi-facet model for mobile users, considering three perspectives, i.e. temporal, locational, and preferential information that help to refine the recommendations. The focus is to recommend popular, trendy and according to the preferences of the users news articles presented on intuitive and easy-to-use user interfaces. It uses PolarisMedia has regional news of Norway and the generated news articles are presented on mobile interfaces adapting the proposed model.

HabitoNews is a personalized adaptive user interface for news readers on mobile devices, i.e. smartphone, for news conception on the go [15]. The user's logs are used to

personalize the news articles they like and prefer based on past history in the HabitNews environment. The news app mimicked the BBC's app as virtual presentation and the news articles are organized using BBC API.

Location-aware personalized news recommendation with explicit semantic analysis (LP-ESA) is a comprehensive hybrid recommendation technique based on deep learning which uses both the interests and the geographical location of the users for recommendation. To address redundancy, sparsity, and high dimensionality in LP-ESA, a new technique LP-DSA (Deep Semantic Analysis). About 63k news articles potentially candidate for recommendation is extracted from about one million tweets of 1.6k user's tweets. The LP-DSA presented good results as compared to the baseline techniques [12].

D. CUSTOMIZED NEWS RECOMMENDATION

This section include studies about news recommendation systems, which emphasis on either a specific community or consider a specific news domain, e.g. news about financial behavior [61], sports news articles [99] and news recommender system for journalists [86].

E-Analyst is a complete system for identifying news articles that can influence the financial behavior of the market [61]. It presents news stories to the news reader who highly indicative of future market trends based on the correlation between news contents and trends in financial time series. The system collects two types of data, i.e. time-stamped news articles and financial time series. The trends are identified by high-level features using piecewise linear fitting and automated binning procedure, and these trends are aligned with the time-stamped news stories and correlated with the trends after learning language models of the news stories using predefined training set. The language model monitored the incoming stream of news and estimated the trend generated by the news. Many data mining techniques can be used to predict market trends [14]. E-Analyst system is evaluated by a traditional approach ROC-style measures rather than the AMOC evaluation measure for similar work [20].

Wesomender is a hybrid context-aware news recommender system for journalists that help to recommend similar news articles published across multiple news sources [86]. Wesomender is a journalist-based recommendation system automatically recommends news based on the group of journalists preferences and fulfill their daily needs.

A word-based model is introduced which contains three steps, i) article distribution, ii) user representation from historical clicks from browser using recurrent neural network, and iii) inner-product between article list and users click using Yahoo's Japan page. The proposed system help to improve the click-rate 23% and an overall improvement of 10% when deployed to the real environment on the smartphone [89].

Odysseus System recommends news articles based on user's events and popularity of news articles using a data stream management system [79].

E. PERSONALIZED NEWS RECOMMENDATION

Personalized news recommendations systems, recommend news from enormous collection of news articles based user preferences and interest that help to optimize the user reading ability in the targeted news. User interests and preferences can be identified in various ways, e.g. using social networks [71], [93] (section V-A), mobile apps [3], [15] (section V-C), Google's news personalization [16], [75], constructing user profiles by click behavior or history logs [30], [75], mobility based news personalization [114] etc. Existing personalized news recommendation (PNR) systems proposed in a number of research articles for effective recommendations of news as per user's need, can broadly be classified based on approaches adapted.

1) CONTENT-BASED RECOMMENDERS

Content-based approach is adopted in the system where similarity is estimated among new published news articles and user's interests. The collaborative filtering technique analyzes the user's news reading history and in contrast, the content-based approach matches the user's news reading preferences in news articles recommendation systems. The hybrid approaches are proposes as alternative of both the approaches to alleviate the weakness of individual techniques [64]. Content analysis is an important task using term frequency based models, i.e. vector space model, TF-IDF [11], topic distribution language models like LDA [29], PLSI [16]. Newsjunkie filter news articles using user's news reading history and by measuring information novelty [25]. Lee and Park presented a mobile web news recommendation system MONERS [62]. It integrates the attributes of news articles with user's reading preferences in modeling process. However, recommendation purely based on content-wise similarities might result in the changeless user interest, which should be avoided in order to broaden users' preference.

2) COLLABORATIVE FILTERING- BASED RECOMMENDERS

In collaborative filtering, personalized news recommendation systems use news reader's explicit feedback in the form of rating, like, etc [16]. Pure collaborative filtering systems recommend items on past historical ratings of individual or a group of users having similar interests [101]. The following paragraphs summarizing news recommendation systems, using collaborative filtering recommendations.

Saranya introduced a personalized news recommendation approach based on dynamic updating policy and collaborative filtering [99]. The study address issues like news context, user access pattern, popularity of news, scalability and recency with the help within Hadoop framework. It includes, building a user model, allowing, understanding and filtering of the user's interest and application of the model to personalized recommendations of relevant news to the user's needs.

Personalized news video recommendation [80] is a collaborative approach for recommending news videos by incorporating topic network with hyperbolic visualization to

recommend news of interest to the users from the large-scale news videos collection. The news videos are collected from three news channels for three months of 4000 news topics. The system recommends news videos based upon the importance and representative score and the algorithm is evaluated for performance of topic detection, response time, accuracy and efficiency.

3) HYBRID RECOMMENDERS

To leverage the strengths and avoiding the disadvantages of both collaborative filtering approach and content-based filtering approach, a number of hybrid approaches need to be introduced. To have more reasonable results, the researchers of modern area combining the basic two techniques to proposed hybrid methods and investigate different solutions.

NewsJunkie is a hybrid personalized news recommendation system and the framework work in two steps [25]. First, the system identifies differences in sets of documents by analyzing the distributions of words and named entities. The framework can be applied to compare individual documents, sets of documents, or a document and a set. Second, a collection of three algorithms (Kullback-Leibler (KL) divergence, Named entities count, Chronological ordering) applied on live news feeds and provides users with a personalized news experience.

Liu presented a personalized news recommendation system based on Bayesian framework by analyzing large-scale Google user's logs for user click behavior to predict their interests [75]. The click behavior is determined by anonymous user's click logs over 14-months duration, randomly sampled 16848 user's click with the minimum of 10 clicks belonging to 10 different countries and regions. The news recommended by calculating and combining both information filter score and collaborative filtering score.

NewsPer is a news recommendation system that has recommended recently published news articles to the users based on the news-reading preferences [30]. The NewsPer system learns the user's interests from their past reading history and constructs a classifier that predicts unread news articles using support vector machine. The system recommends articles based on two things, i.e. the news similar to the articles read by the user and dissimilar to the articles skipped by the user in the past.

SCENE is a two-stage or two-level scalable, personalized news recommender system [65]. In first-stage, the news articles are clustered based on user's preferences and specific news articles in second-stage. The system is able to deal with large scale news articles collection by exploring the intrinsic relationship among users with news articles. The SCENE recommends news to the readers based on considering the popularity and recency of news articles. The SCENE is experimentally evaluated for efficacy and efficiency after collected real-world news articles from two known websites of nine categories along with user's access history over a period of three months.

A multi-phase hybrid personalized news recommendation system at Forbes.com website is proposed by [56]. The method with the best CRT is the combination of Wikipedia-based concept features and post-processed by a novel Bayesian remapping technique. In first phase of the two phases, a historic dataset of 8.5 millions article URL clicks used to identify unique users for a quick test. In second phase, a live trial is conducted on Forbes.com website over a period of five months, 2.1 millions article URL clicks used and 82,000 unique users are identified.

PEN recsys is a personalized news recommendation system framework [27]. The framework is online evaluated and used by the news website *swissinfo.ch*. PEN recsys is designed to keep 4 things into consideration, i.e. it should be fast (provide real-time recommendation), reliable (avoid failure), flexible (easy to add new component) and scalable (handle large-number news articles and unpredictable user's visit peaks). PEN recsys framework followed hybrid recommendation approach, which contained various algorithms from context-tree recommendation, a simple collaborative filtering, content-based approach, most popular articles, and random articles. The focused was to design a time-efficient framework and hence PEN recsys is evaluated both online and offline to analyze the performance for both the settings.

A class of online news recommendation system based on the context-tree is introduced in [26]. The Context in the recommendation system can be the set of sequences of news items, sequence of topics, or a set of topic distributions. If new news item added means more context to be added. To make accurate news recommendations each context is associated with a set of prediction model called expert and the expert model considered the popularity and freshness of news articles.

LOGO is news recommender system for online news readers, which seamlessly integrate LOnG-term and shOrt-term reading preferences of the reader [66]. An extended experimental study of LOGO on the evaluation of user's interests in news recommendation systems, and proposed a recommendation technique based on the long-term and short-term news reading preferences of the user [67]. In long-term profiling, the user's reading preferences are seamlessly incorporated with hierarchy of new published news articles and news groups preferred by that user. In short-term profiling, the selected news group and a list of news articles are chosen as the recommended candidates.

The [28] evaluated various news recommendation systems online by implemented the algorithms on *swissinfo.ch* website with live traffic and PEN recsys framework [27]. The *swissinfo.ch* news website holding contents in 10 different languages for audience form all over the world. The techniques are deployed to English version of the news website. The study showed that, in online settings context-tree recommendation system [26] click-through rate improved by 35% and the visit length also increases by a factor of 2.5.

A subscription-based news recommendation algorithm is introduced based on hybrid approach [106]. The algorithm

needs two steps to capture user's preferences and interests, i.e. during subscription the user must provide their preferences (content-based) e.g. like news related to sports or entertainment, etc. from pre-defined categories, and optional feedback (collaborative filtering) for updating user interests.

A hybrid story recommendation technique introduced by using co-commenting patterns of users from two forum-based social networks. The approach combines the collaborative features and content-based features from the learn-to-rank framework and uses 250 users profiles and comments for experimentation [4].

To efficiently handle sparsity problem in news items, a hybrid personalization approach is introduced. The correlation coefficient formula is improved by adding hot news parameters to get better news recommendation results. The experimentation is done on 150 news articles collected from local news website and 10 thousand user's rating data [76].

CHAMELEON is a Deep neural network-based Meta-architecture for news personalization and recommendations by utilizing both news item features and user's search history to address cold-start problem and context-dependent relevance [17]. The study is further extended to introduced recurrent neural network (RNN)-based model by adding content and contextual information to get more accurate results [24].

DKN (Deep Knowledge-aware Network) is a multi-channel and word-entity-aligned personalized news recommendation system that merge both semantic-level and knowledge-level representations of news [116]. Similarly, a deep reinforcement learning framework "DRN" to facilitate newsreaders [123].

A feature-aware representation learning technique, deep fusion model (DFM) was introduced based on item retrieval and item ranking [70].

It is difficult to capture user's long-term, short-term user's representation of their interest and topic-aware representation for accurate news personalization where recurrence and convolutional neural networks plays very important role in the recent era [2], [119].

F. GENERAL CATEGORY OF NEWS RECOMMENDATIONS

This section included news recommendations systems, which not fall in all the above categories.

1) CONTENT-BASED RECOMMENDERS

Tintarev and Masthoff [111] discussed content-based similarity measures named Lin's [73] and WASP measures [54], and the results of Lin's and WASP measures are compared with human judgment based on news headlines. For evaluating Lin's, WASP and human judgment, the news headlines were considered from Google's news originated from South African, British, and American English news editions of various categories such as Entertainment, Sports, World News, and Technology news. The results of Lin's and WASP measures are compared with human judgment by calculating means and standard deviations.

Bogers and Van den Bosch [5] adopted information retrieval probabilistic algorithms for news article recommendation on the collection used in Ad-Hoc tracks of TREC 1-5 [115]. Three algorithms, Okapi (classical probabilistic retrieval model) [95], LM (language modeling framework) [97] and tf.idf is considered for recommending news articles and significant performance gained.

The News filter and summarization (**NFAS**) system [120] automatically recognize news web pages and extract news page's title, news contents and key phrases by filtering non-news contents, i.e. layouts and styles of web pages.

Vietnamese news recommendation system is a content-based recommendation system that analysis user's interest with hidden topics [112]. Topic model is used to display semantic relationships of words and terms in news articles. Topic analysis models are powerful tools that identify patterns in structured or unstructured collections of text corpus. The proposed model constructed user's interest model and then labeled hidden topics from the set of news articles.

A content-based news recommendation system is introduced based on cosine-similarity search which uses devised effective article representation [58]. The proposed approach follows three steps i.e. computing article similarity (preprocess the article to reduce processing overhead, compute cosine-similarity for each article), User model creation (based on implicit user's feedback extracted from server logs) and article recommendation (based on both earlier steps).

TRECOM is a news recommendation approach using incremental hierarchical clustering based on text similarity and user behavior, which recommends news, based on the contents of news article and user history logs [122]. The proposed approach follows three steps, i.e. discovering user's interest (from history logs), retrieving suggestions (using similarity-tree) and compiling recommendations (using text similarity and user behavior).

The *contextual bandit* news recommender algorithm proposed for unbiased evaluation [68]. The log data is used in proposed algorithm rather than using a simulator. The evaluation is conducted using news collected from the Yahoo! Homepage and empirically validated for recommending online news articles. The proposed technique demonstrated appreciable results for both stability and accuracy.

The study [81] introduces a content-based news recommendation system using topic models. The performance of the system is evaluated with small group of users (total 16 users), three standard classification methods, i.e. Naïve Bayes (NB), K-Nearest Neighbor (KNN) regression and Regularized linear Regression (Lin) in novel online simulation settings, and adopted two topic models, i.e. Latent Dirichlet Allocation (LDA) and Singular Valued Decomposition (SVD).

Recommendation of items like movies, music, products are generally recommended by using collaborative filtering techniques where user's past interaction with the system is considered for new recommendations. While in practice,

recommendation of news articles scenarios are different from traditional models, i.e. the recommendation is often be generated without consulting user's preferences and past access history [98]. The study [98], analyzed two approaches, i.e. recency-based and document similarity-based, on four news sources, which further categorized into two, i.e. general news and topic focused. A traditional online newspaper and a sport news website for general news articles, while an automotive news website and a gardening website for topic focused news articles, e.g. motor talk from automotive and computer woche from IT & business. The analysis has been done on 10-days data from Plista news recommendation service collected while participating in the 2013 news recommendation challenge [109]. The recommendations were either based on news article similarities (title and leading paragraph of the currently read article used as a query for similarity) or on the recency of the articles (the most-recent articles published online).

Most Popular algorithm is a proposed highly scalable news recommendation technique [113]. The main objectives were to develop and evaluate a news recommender system that handles three challenges, i.e. scalability, response time and continuously changing the collection of users and news items. It is a asynchronous and distributed news recommendation approach built using a scale well AKKA framework (http://akka.io/).

Probst et. al. extended the previous scalable algorithm [113] and introduced three algorithms for scalable, distributable real-time news recommendation system [96]. The main focused was to optimize the news recommendation precision and handle four challenges, i.e. the continuous changes in the set of items, the context-dependent relevance of items, scalability and response time. They introduced three algorithms namely Most Popular Items (most clicks), Most Recent Items (recently published), and Most Recent Items of the Most Popular Categories (most recent item in a category) using the AKKA framework. The approach determined the importance of news article in last 15 minutes to be recommended. Both the studies [96] and [113] are evaluated online for Click Through Rate (CRT) and compared all the three proposed approaches. The two implemented recommenders are analyzed by two timeframes of 4-days and one week consecutively.

A widely used technique single value decomposition (SVD) technique by regularizing two different variations and is used to handle data sparsity problem in news recommendation. The experimentation is performed to analyze the proposed approach for XMUNews and movielens datasets [43].

A deep neural network-based news recommendation system presented to handled two problems, i.e. cold-start regarding news items and users, and user's interest variations. The proposed approach is evaluated both online and offline considering NewsREEL dataset. The model presented good results and slow down the cold-start problem of users and items [60].

In the news industry, the editor plays a vital role, and a section contains editor preference. The selection is non-explicit and more depends on the attractiveness and quality of writing of the news articles. A meta-attention model is introduced to learn and automate the editor's selection criteria based on multiple deep neural nets [117].

2) HYBRID RECOMMENDER

A number of algorithms introduced for recommendation news articles based on Plista Open Recommendation Platform in the scope of the CLEF-NewsREEL 2014 challenge [18]. The study introduced three types of algorithms for online news recommendation, i.e. six popularity-based recommenders (basic, geolocation, item categories, weekday, hour, freshness), seven content-based recommenders (title, summary, new, fresh, keywords, entities and context), an ensemble recommender, a recency-based recommender and a feedback-based recommender, 16 algorithms in total. The system is evaluated on a sample of one-week news articles collected from 11 online news sources as discussed in [55]. The collection contained news articles from domain-specific news, e.g. sports, general news to online home and gardening stores. There is a notable overlap of users or visitors for sport website (sport1.de) and gardening store website (wohnen-und-garten.de) but less frequently visit motor-talk.de website.

A study combines text snippets and annotated images for news recommendation after text-image analysis on news collection from four different German news sites [77].

An efficient monotone submodular function based on the streaming algorithm is used for the recommendation of news and scientific literature for both time as well as space efficiency [121].

StreamRec is an open-source framework for replay-based news recommendations that can adapt underlying models in real-time after collecting data about news events [46].

Utility-based recommendation system (URecSys) uses two-stage framework by combining articles-level and probabilistic topic models to handle cold-start problems in news recommendations [124].

Reference [92] proposed a system that uses to calculate bias score for news articles during recommendation to find out the fake or biased news articles.

G. NEWS RECOMMENDATION SURVEYS

This section included surveys of news recommendation systems and studies that compared all three common approaches, briefly discussed below and summerized in Table 6.

An empirical study that discussed a number of studies about personalized news recommendation systems based on three basic approaches, i.e. content-based, collaborative-filtering and hybrid approaches is presented in [64]. The study designs a set of experiments to evaluate the personalized news recommendation systems empirically using dataset from SCENE [65].

TABLE 6. Comparison of survey papers in the domain of news recommendation.

AID	Challenges	Studies	Paper Organization	Statistical Analysis	Remarks
[A44]	13	12	Six Challenges	No	Generic News Recommendation Survey
[A45]	05	07	Studies in Sequence	No	Generic News Recommendation Survey
[A48]	05	10	Supervised and Unsupervised Techniques	No	Profile-based News Recommendation Survey
[A81]	04	140	Main Recommendation Approaches	Yes	Comprehensive Review of News Recommendations, Criteria not defined
2019	21	81	Six Categories	Yes	Comprehensive Review of News Recommendations

The [29] compared collaborative filtering, content-based and hybrid approaches for personalized news recommendation. In collaborative filtering, news article reading history of the user is considered and recommends those articles which are read by the users having similar interests. The content-based approach is considered to avoid the cold-start problem and recommends similar items that are read by the user previously using the topic model. They used a method named bag-of-news recommendation system for collaborative filtering and LDA (Latent Dirichlet Allocation) for the content-based approach.

A **survey** on news recommendation methods and challenges in the news domain is presented by [90]. The study divides the news recommendation techniques based on the problem or challenge addressed. They discussed 13 challenges in general without mapping it at news domain, included 12 different studies about news recommendations and classified all the news techniques in six challenges addressed, e.g. cold-start problem, recency, implicit feedback, changing user interest, scalability, sparsity of data.

A brief **survey** [19], about news recommendation systems, which discussed six news recommendation approaches, five challenges in news recommendations, include seven studies for news recommendations. They also discussed topic analysis model or probabilistic models to discover a useful pattern in the document collection text corpora.

Another brief **survey** on user profiling in news recommendation systems is introduced by [37]. The study implicitly included about five challenges (short-term, long-term user's preferences, changing interests, explicit feedback of the user) and 10 studies of common user profiling techniques. The focus is to classify the supervised and unsupervised machine learning techniques discussed user profiling in the news recommendation systems, considered very few latest papers from latest literature.

A comprehensive review paper is published in 2018 spread over a period of nine years and 140 papers (criteria not explicitly defined), i.e., 2006-15 [47]. The study included papers explicitly addressed four challenges, i.e. Cold-start problem, recency, scalability and Datasets evaluation.

VI. RESULTS ANALYSIS & DISCUSSIONS

This section discusses the statistical outcome of the information extracted from the studies included for this paper and answered the questions raised in section III-A.

A. RECOMMENDATION APPROACHES

The recommendation approaches adaptation is depends on the application domain and related contents, the challenges faced and the requirements of the targeted community. The Collaborative Filtering (CF) technique suffers from many challenges, which depend on the user's willingness and explicit feedback. It is rarely applied recommendation approach for news recommendation, eight studies (13%) applied CF approach for news recommendation during last 14 years, and the CF is a common approach in news personalization and mobile news recommendation. The Content-Based (CB) is the most applied approach to news recommendation during 2010-13, 20 research articles (27%) of 81, the main application area of CB technique is semantic-based recommendation and specific news websites. To avoid disadvantages of both CF and CB approaches Hybrid approach is adopted to combine good qualities of both the techniques. It has been observed that Hybrid approach is exhaustively used for news recommendation since 2010 (i.e. 60%), because the challenges of a technique can be overcome by the complemented technique when applied to a platform. The distribution and trends of the usage of these approaches is shown in Fig 3 [52].

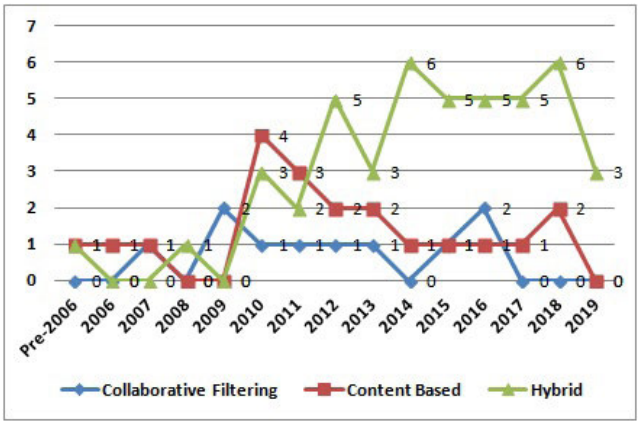

FIGURE 3. Approaches adopted in news recommendation systems.

B. EFFICIENCY ESTIMATION

The main goal of recommender systems is to provide meaningful recommendations from a collection as per requirements of a specific community. So, the authors focus on

accurate and satisfactory results of the system rather than efficiency. The proposed algorithms should be analyzed for two factors (or even three factors, memory is third factor, which is not an issue now), i.e. efficiency and accuracy. All most, all the studies focus on accuracy either by considering precision, recall, F-measure or user's satisfaction, etc., because the focus is only on recent news, i.e. recency. There are very little number of recent news as compared to the overall collection and hence the efficiency of the proposed technique is acceptable. If the relevancy of item is considered for a huge collection then the time efficiency become critical to analyzed such a news archive. Computational complexity is important part of the evaluation process, may be less relevant to the researchers but highly relevant to the recommender system providers. It is important to estimate the efficiency of recommender system for exponentially large datasets especially in scalable and dynamic environment of news domain. For long-term suitability of an algorithm or framework for news recommendation, it should perform for few news items and few users, may perform well when scale to huge collection of news items and users.

C. DATASETS USED

There is no standard or baseline dataset that can be used for analysis of proposed algorithms or techniques and rightly so because the dataset selection depends on the scenario of the evaluation settings. For example, to find the popularity of news articles using a social network like Twitter [44], the news article's collection and Twitter messages would be from the same point of time. In such scenario, the standard or predefined baselines cannot be applied. Out of 81 studies, 51 studies little talked about the news article collection or dataset used for evaluation. Nine studies (18%) are evaluated using known news aggregator services, i.e. Google's news [16], [75], [111] and Yahoo's news [68], Bing news [70], [116], MSN news [2], [119]. The SCENE dataset is also used in four (8%) different studies [64], [65], [71], [72]. There is no consistency in news articles size by news count, type of news, and news sources, etc. In conclusion, the question is raised how reliable the results are to be compared? Because, no two studies conducted by two different researchers performed experiments using the same dataset. Jon et.al. introduced a news article dataset from Adresseavisen's news portal, covering both collaborative and content-based component for advanced news recommendation systems [35].

D. e-NEWS SOURCES

The lack of standardized dataset(s) leads the inconsistency in the selection of e-news sources. There are many e-news sources which covers regional, national and international events and target a specific community. The news industry is trying to facilitate their users and performing experiments on their news platforms and most of the studies resulted in one e-news source evaluation and 24 (30%) studies does not discuss the news sources clearly. After carefully analyzing the news recommendation studies the e-news sources can be categorized as shown in Table 7.

TABLE 7. Number of e-news sources.

# E-News Sources	# of Studies
1 E-News Source	26
2 E-News Source	14
3 E-News Source	2
4 E-News Source	4
5 E-News Source	2
5+ E-News Source	2
News Aggregators	5
3 TV Channels	1

E. EVALUATION APPROACHES

It is difficult to compare system-driven evaluated studies, adopted different approaches because of the lack of standardized news articles collections. The evaluation approaches can be classified into two broad categories, i.e. offline (not in real environment and using test dataset) and online (in real environment with real users and run-time news). Out of 81 studies, 62 studies discuss evaluation approaches in which 38 (61%) studies evaluated offline, 16 (26%) studies evaluated online and 8 (13%) studies evaluated adopting both offline and online. Most of the online evaluated studies are done with single e-news sources, e.g. [28], [56] and few with news aggregator service Google, e.g. [75]. The validity of offline and online evaluations in dynamic environment like news domain, and demand further research verifications.

F. CHALLENGES ADDRESSED IN LITERATURE

The literature reviewed for this study encountered very few challenges to be addressed from a long list of challenges in the news domain as identified, categorized that can be encountered in adapting different recommendation approaches in section VI-F. Those challenges are included, which were explicitly observed in the research papers, 48 (60%) studies addresses twelve different challenges directly and with emphasize, i.e. cold-start problem, recency, change in user set or item set, scalability, sparsity, context-dependent relevance, change in user's interest, response time, user modeling, explicit user's feedback and topic divergence. However, four of the challenges are highly focused and discussed throughout the literature, i.e. cold-start problem (address in 13 studies), recency (16 studies), scalability (10 studies), response time (9 studies), change in user's interest (9 studies) and sparsity (7 studies) as highlighted in the Table 8. A number of challenges were not addressed yet. There are some interdependent challenges, i.e. if you handle one, the other can cause problem. The selection of recommendation approach is normally depends on the application domain, contents of the news, the interest level of newsreaders and many other features.

TABLE 8. Highly focused challenges in literature.

Challenges	References (AIDs)
Cold-Start Problem	[A06][A10][A12][A24][A27][A35][A46][A56][A58][A62][A63] [A69][A76]
Recency	[A01][A05][A18][A19][A28][A30][A33][A35][A40][A41][A47] [A57][A58][A60][A67][A78]
Scalability	[A06][A08][A11][A12][A19][A28][A43][A51][A53][A58]
Response Time	[A04][A07][A08][A11][A17][A18][A43][A51][A53]
Sparsity	[A10][A27][A46][A56][A61][A62][A65]
Context-dependent Relevance	[A28][A56][A67][A69][A73][A78]
Changes in User's Interest	[A05][A21][A45][A63][A69][A76][A78][A79][A80]
Changes in Item's Set	[A51][A53]
Unpredictable Behavior	[A64]
User Modeling	[A64][A71][A73]
Explicit User's Feedback	[A71]
Topic Divergence	[A14]

TABLE 9. Conclusive summary (answer to the questions).

Q-1 : What are the different challenges facing by news recommendations domain?
The literature is comprehensively studied and identified 21 challenges are categorized as;

- *CF* : Cold-start Problem, Explicit User Feedback, Continuous Changes in User Interests, Topic Divergence, User Modeling, Privacy, Gray Sheep, Context-Dependent Relevance, Unpredictable Behavior, Unwillingness of Users to Register, Using Shared Devices.
- *CB* : Recency, Continuous Changes in News Items Set, Unstructured Content, Response Time, Multiple Sources, Cross-Lingual news items.
- *Hybrid* : Data Sparsity, Scalability, Serendipity, Fraud.

Q-2 : How to classify the news recommendations systems based on a specific domain?
The studies are classified based on main application domains, i.e. Social networks, Semantic-based, Mobile-based, Personalized news recommendation and customized recommendation, in which personalized news recommendation is the main focus area for researchers in the last decade by applying hybrid approaches.

Q-3 : Up to what extent the common recommendation approaches (CB, CF or Hybrid) are adopted?
The hybrid approach is exhaustively used in news recommendations since 2010 (about 60% research studies used the hybrid approach) and mostly used for news personalization, and the CB recommendation approach is adopted for specific news platforms and semantic-based studies.

Q-4 : How do authors provide information about Efficiency of algorithms or techniques applied?
The researchers mostly emphasize on accuracy rather than efficiency. The efficiency matters when the news items are recommended from the huge news collection as compared to the limited number of recent news. It is important to estimate the efficiency of a recommender system for exponentially large datasets especially in the scalable and dynamic environment of the news domain.

Q-5 : Which datasets are used? Do the papers provide sufficient information about the dataset?
There is no baseline dataset that can be used for the analysis of proposed algorithms or techniques because the dataset selection depends on the scenario of the evaluation settings. 70% of the research studies very little talk about the dataset and other related details.

Q-6 : What are the e-news sources used for the news recommendation studies?
The industry is trying to facilitate their newsreaders and hence consider their own single or two e-news platforms. Mostly (72%), the news recommendation research used a single e-news source and two e-news sources, i.e. 47% and 25% respectively, for news collection, experimentation and evaluation.

Q-7 : How the evaluation is conducted for the news recommendation studies?
The evaluation settings were explained by 79% studies in which offline is 61%, online 26% and 13% studies evaluated the proposed techniques using both offline and online approaches.

Q-8 : Which challenges are explicitly tackled?
There are many challenges in news recommendation and very few (57%) challenges are directly addressed in different studies, where the emphasis is on five challenges, i.e. Recency, Cold-Start Problem, Scalability, Response Time, and Changes in User's Interest, which indicates that the news recommendation is an open field to research in different application domain.

VII. CONCLUSIONS

In this paper, we set the background knowledge about recommendation systems, the broad categories, sub-categories, and designed questions for the study. We comprehensively illustrated the research methodology, data collection strategy, inclusion & exclusion criteria, quality assessment criteria, and the main resources consulted. The focus is to answer the designed questions in section III-A. To answer Q1-Q8 we studied eighty news articles in the time span of 14 years, we identified and categorized twenty one challenges faced in news recommendation which can help in developing better recommendation systems if addressed. The recommendation systems are classified into seven different categories and briefly discussed each study to ease the understanding and also discussed the statistical facts and figures extracted from the selected papers. Table 9 is summarized the outcome of the paper to address the designed questions.

VIII. FUTURE RESEARCH DIRECTIONS

Some basic questions are keenly investigated in section III. Moreover, Section VI provided guidance for the work done in the field of news recommendation. It also provides guidance for further research and explore different dimensions. Here are some guidelines that can be helpful in designing a well-tuned news recommender system.

1) To create a set of baseline datasets, that cover different scenarios applying different recommendation approaches and define its evaluation settings. Define criteria for a good news articles datasets. For example, a dataset which contain news articles from a specific category(ies), Twitter messages with user's log over a same point of time for social media (Twitter) based news recommendation techniques with observed estimated relevancy results. Baseline or standardized dataset helped to distinguish and compare results and performance of different techniques.
2) Most of the literature ignores the efficiency of the proposed algorithms or techniques. Efficiency and accuracy of expected results should be measured for acceptable response time of recommendations. Each technique should be evaluated for both offline mode and online real-time mode to clearly assess the efficiency and behavior of proposed techniques using single or multiple different datasets.
3) News recommendations from multiple sources either using news aggregator like Google's news or any other alternative for hybrid techniques or content-based technique to reduce third party dependency by carefully observed news article attributes.
4) To consider the challenges explicitly in the write-up and experimentations when applying news recommendation approach and clearly devised techniques for improvement.
5) Modeling an individual is one of the difficult tasks and knowing their interest, because the short-term and long-term preferences are event-based and varies. To frame the interests and preferences of a targeted group rather than an individual may eliminate many shortcomings of the collaborative filtering approach and produced efficient precise results, e.g. community-based news recommendations.
6) Relevancy of news article is a subjective matter and the perception varies among individuals. Two news are relevant according to a news reader may, may not be relevant by another news reader because relevancy is subjective judgment of an individual. Effective relevancy is continuous not binary and difficult to make a judgment about. The relevancy depends upon many standpoints from a human perspective [82], i.e. relevancy is;
   - *Subjective*: Varies individual to individual and depends on specific individual judgment
   - *Situational*: Related to user's current needs
   - *Cognitive*: Relies on human perception and behavior
   - *Dynamic*: Changes over time or events

   Relevancy is often equated with relatedness or connection among news articles. The news readers read about a happening or an issue from various sources in order to get a broader perspective and diverse viewpoints that help to better understand the world around, and some time to authenticate the information itself by comparing similar news from multiple news sources. Three phrases "same news, similar news and follow-up news" convey different meaning but use sometimes alternatively, as breifly explain below;
   - *Same news* means two news represents the same event, e.g. "M 4.5 Earthquake in Yukon Territory Canada" and "M 4.5 Earthquake in Yukon Territory Canada is 138 km from Whitehouse" two news articles represents the same event reported by two newspapers.
   - *Similar news* means that the news articles address alike events, e.g. "M 4.3 Earthquake in Yukon Territory Canada" and "M 6.3 Earthquake in Yukon Territory Canada" two articles represent alike events, i.e. earthquakes in Yukon Territory Canada.
   - *Follow-up news* means news is followed by news that shows recent development, e.g. news "M 6.3 Earthquake in Yukon Territory Canada" followed by news "Multiple aftershocks Jolt the Yukon Territory after Strong Earthquake" or "The Government-Imposed Emergency after Yesterday Strong Earthquake in Yukon".

   The relevancy of the news recommendation should be clearly presented in the study that helps to think about improvement in different dimension.
7) News recommendations in News Archive, e.g. DNSA [51] in Digital News Stories Preservation DNSP) framework [50], [53]. In archives recency is less important than exact information relevance. The DNSA has news articles from multiple sources, needs to create a mechanism that helps the reader to read a set of relevant news stories about an event or issue. The DNSA needs an efficient mechanism to recommend the digital stories to the news readers and will lead the reader to browse through the huge collection, easily. Without a suitable and efficient mechanism to identify relevant news, online newspaper would be nothing more than a data collection. A link can be created in two different ways in the DNSA, namely vertical linkage and horizontal linkage as shown in the Fig 4.

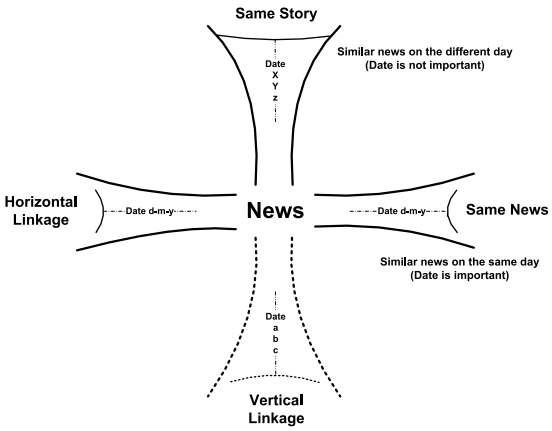

FIGURE 4. Linking digital news stories in DNSA.

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- *Vertical Linkage*: In vertical linkage, the link should be created between the news which represents the ''same story or follow-up news'' regardless of the timeframe based on all the news preserved in the DNSA. Same story can be interpreted as the follow-up news about an issue or a same subject from the same source or from different sources. For example, ''Supreme Court proceedings about Panama leaks''. Same story linkage of news leads to Follow-up Similarity between news for more days since the start of proceedings.
- *Horizontal Linkage*: In horizontal linkage, the link should be created between the news which represents the ''same news'' based on all the news preserved in the DNSA in a specific time. Same news can be interpreted as the similar news reported about an issue or a subject from the same source or from different sources. For example, ''Supreme Court response to the arguments on Panama leaks''. Same news linkage of news leads to find similar news on the same day and same time.

APPENDIX

In this appendix, the unique IDs are assigned to the shortlisted primary articles (AID-Article ID) that discuss recommendation systems in the News domain. These assigned AIDs/tags are used to represent in different tables to group them purposely. Table 10 contains the tags which represent the news recommendation systems discussed in the articles.

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