

A KNOWLEDGE-BASED RECOMMENDATION SYSTEM THAT INCLUDES SENTIMENT ANALYSIS AND DEEP LEARNING

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ABSTRACT

Online social networks (OSN) provide relevant information on users' opinion about different themes. Thus, applications, such as monitoring, and recommendation systems (RS) can collect and analyse this data. This paper presents a Knowledge-Based Recommendation System (KBRS), which includes an emotional health monitoring system to detect users with potential psychological disturbances, specifically, depression and stress. Depending on the monitoring results, the KBRS, based on ontologies and sentiment analysis, is activated to send happy, calm, relaxing, or motivational messages to users with psychological disturbances. Also, the solution includes a mechanism to send warning messages to authorized persons, in case a depression disturbance is detected by the monitoring system. The detection of sentences with depressive and stressful content is performed through a Convolutional Neural Network (CNN) and a Bi-directional Long Short-Term Memory (BLSTM) - Recurrent Neural Networks (RNN); the proposed method reached an accuracy of 0.89 and 0.90 to detect depressed and stressed users, respectively. Experimental results show that the proposed KBRS reached a rating of 94% of very satisfied users, as opposed to 69% reached by a RS without the use of neither a sentiment metric nor ontologies. Additionally, subjective test results demonstrated that the proposed solution consumes low memory, processing, and energy from current mobile electronic devices.

Key Words - Sentiment Analysis, Deep Learning, Online social networks

1. INTRODUCTION

The number of active online social network (OSN) users has grown considerably, and some studies indicate there will be 2.95 billion users by the end of 2020 [1]. This high number of users, on OSN, is mainly due to the increase of the number of mobile devices, such as smartphones and tablets, connected to the Internet. Currently, OSN have become a rich and universal means of opinion expression, feelings, and they reflect the bad habits or wellness practices of each user. In recent years, the analysis of the messages posted on OSN have been used by many applications [2], [3] in the industry of health care informatics. The sentiments and emotions, expressed on the messages posted on OSN, provide clues to different aspects of the behaviour of users; for instance, sentences containing words Renata L. Rosa and Demostenes Z. Rodr'iguez are with the Federal University of Lavras, Brazil. CEP: 37200-000. Gisele M. Schwartz is with Universidade Estadual Paulista Julio de Mesquita Filho, Biosciences Institute of Rio Claro, Brazil. CEP: 13506-900. Wilson V. Ruggiero is with the Polytechnic School of the University of Sao Paulo, Brazil. CEP: 05508-010. With negative meaning may indicate sadness, stress, or dissatisfaction [4]. Conversely, it can be inferred that if a person is in a positive mood state, this person can be more self-confident and emotionally stable [5]. Users have different behaviors on OSN, if the sentiment intensity value of posted sentences remain at low levels, or if it frequently changes from high to low levels and vice versa, these facts can indicate some emotional disturbance, such as depression or stress events [6]. Hancock, Gee, Ciaccio et al. [7] and Liu [8] observed that users write short sentences when they are experiencing a period of depression. Also, these users use the first person pronoun in their sentences and suffer from chronic insomnia. Therefore, their behavior can be reflected in the sentences posted on OSN. The presence of certain words in the sentences can be monitored and analyzed to identify users at a high risk of attempting suicide and an appropriate intervention can take place [9]. Depression is one of the most prevalent mental disorders in all regions and cultures around the world [10]. Unfortunately, depression recognition rate remains low. Most of the studies about health systems [11]–[13] use sensor devices to detect mental disorders. In [14], the proposed trained classifier, which is trained using electroencephalogram signals, is able to detect stress with an average accuracy of 80.45% using 4- fold cross validation. In [15], authors use heart rate variability data to propose a classification model that considers different stress levels, baseline, mild stress and severe stress, reaching accuracy values of 74%, 81%, 82%, respectively. There is a scarce number of studies that use textual information from OSN data to detect physiological disorders. Xue et al. [16] use different machine learning (ML) classifiers to perform emotion classification focused on psychological disorders from micro-blogs, reaching an average accuracy of 80%. In [17], the proposed model to detect stress based on the information of Twitter activities reached an accuracy of 69%. In [18], authors study the causes of postpartum depression using OSN information. ML algorithms are also used in

studies about mood monitoring systems analyzing messages from OSN [19], reaching an accuracy of 57%. Ma and Hovy [20] introduce a network architecture to analyze sentences meaning through character-level representations by using a combination of Long Short-Term Memory (LSTM), a Convolutional Neural Network (CNN) and Conditional Random Field (CRF). Lample et al. [21] combine Recurrent Neural Networks (RNNs) with CRFs to obtain the best results on Named Entity Recognition (NER) datasets. A bi-directional LSTM (BLSTM), an improved version of the LSTM, is also used for labeling tasks. The deep learning approach has been explored in several areas [22], such as personality analysis [23], age group classification on OSN [24], sentiment analysis [25], among others. However, this approach is not widely explored in psychopathology studies. In this context, our study intends to test the performance of deep learning algorithms in scenarios of depressed, stressed, and non-depressed and non-stressed users' detection. A Recommendation System (RS) application can be used as a method to enhance the user's emotional health, improving the person's mood in case of negative emotional states [26]. RS based on ontology is being used for health purposes [27], presenting reliable results from diseases treatment plans. In this context, the main goal of this work is to introduce an RS that uses an approach named Knowledge-Based Recommendation System (KBRS), which aggregates an ontology collection for health scenarios, named Nuadu [28], which is not addressed in other RSs designed to improve emotional health. The proposed KBRS also includes the sentiment analysis approach and an emotional health monitoring system. The monitoring system filters sentences from an OSN that allows to identify potential users with depression or stress conditions. To accomplish this task, an objective method based on a BLSTM-RNN is used to detect potential psychological disorders, along a CNN. Later, a KBRS is activated to send happy, calm, relaxing, or motivational messages to these users. These messages have different intensity levels depending on the sentiment intensity of the sentences posted on an OSN, which is determined by an enhanced sentiment analysis metric, eSM2. This proposed metric is based on a word-dictionary, considering the Portuguese language, and enhanced with additional information such as user's profile data, user's geographic location, and the theme of the sentence. Furthermore, in the cases of depression detection, the solution sends warning messages to authorized people who are previously registered in the system. According to the subjective test results, users reported high satisfaction with the KBRS, improving their emotional states. Tests were also performed with a traditional RS without the Nuadu ontology and the eSM2 for comparing it with the proposed KBRS. Furthermore, subjective tests reported that the application running on the user mobile electronic device had low complexity and low-power consumption.

2. LITERATURE SURVEY

Here, we have discussed different models that combine textual data with Recommendation System algorithms providing recommendations to the users. In [11], a brief about text classification using Capsule Networks (CN) has been explained. The different hybrid recommendation systems that have been proposed by the researchers that combine textual data and recommendation algorithms are explained further. CTR, Collaborative Topic Regression [30], incorporates the advantages of collaborativebased, MF algorithm and probabilistic topic modelling approach for recommending research-based articles to the scientists online. Content analysis is done using the Topic modelling approach (LDA) combined with latent factor models using MF for recommending the unseen articles [28]. Their approach worked well as it recommended completely unrated articles to the users that were useful and hence, predictions were made in the right manner. Various efficient algorithms have been proposed in further years that have worked upon these models and have improved them. In HFT [19] model, the authors have developed a statistical model that combines hidden dimensions in the rating matrix with the topics extracted from the text of the review given by users. This methodology helped in predicting users' rating on unseen movies and further recommends them. The models developed by them helped in the discovery of genre and identified the most informative reviews. Their model "HFT", Hidden Factor Topics has addressed the most occurred problem in recommendation tasks, Cold-Start. Their model performed better than the latent factor-based recommender system improving accuracy by 5–10% [32]. The model RMR [17], proposed by the authors, have combined the contentbased and collaborative based filtering techniques to develop a novel integrated recommender system. Their model "RMR", Rating meets reviews combined the rating model with a topic model to generate recommendations and thereby solving the "cold-start" problem, that is recommending the new products to the users that have not been rating using the description of the item. Their model also works on the side of the item. For modeling the ratings, they have used a mixture of Gaussian, unlike above researchers that have used MF method. They have compared their model with the above described, HFT and CTR and has shown that their model has performed better in terms of rating prediction accuracy. CDL [32], Collaborative Deep Learning brought a change in the topic modeling approach by learning the numeric representation of textual data by applying deep learning techniques on the item description document. In this paper, they have proposed the hierarchical Bayesian Model, which applies deep learning on the textual data and Collaborative filtering approach on rating data in a joint manner. They have used SDAE, Stacked Denoising Autoencoders, neural network approach combined with the

Collaborative Filtering method in order to integrate the rating and content information, thereby advancing the quality of recommender systems. Convolutional Matrix Factorization (ConvMF) [14], this model addresses the rating data sparsity by learning the text document using single CNN. The CNN considers the surroundings of the word order that has improved the representation of latent features in the description of the items' documents. Their model integrates PMF and CNN to upgrade the rating prediction task and hence, refine the quality of recommendation of items or movies to the end-users. LZhang et al. [35] proposed combining CF algorithm with an artificial neural network (ANN) to enhance the scalability and remove the sparsity of recommendation systems. Quadric Polynomial Regression model extracts the latent features, and these features then becomes the input to the deep neural network for predicting the rating scores. The model used to extract the hidden features improves the traditional matrix factorization method [35]. Dual-Regularized Matrix Factorization (DRMF) [34], this is the recent research work in the field of integrating textual data description with PMF. They have exploited the textual description of items and users both and then predicted the rating score. They have also adopted a unique multi-layered neural network model that combines CNN and bi-directional GRU that has given a better latent representation of the text. The content representation regularized the latent models for the items and users in MF. Different expert recommendation systems have also been designed to recommend the experts in different domains for solving problems using the information retrieval process. It helps in the detection of knowledgeable people expert in his or her area. The combination of search engines and NLP can be used to retrieve the experts in this kind of recommendation systems [12]. Different tags and their syntactic patterns associated with Web 2.0 such as audio, video, movies can be exploited for recommendation to solve the cold start problem [1, 23]. This research paper is being inspired by the above-related work explained. Our proposed approach brings an improvement in the text analysis model so that the textual representation gets better, thereby improving the quality of recommendations.

3. PROPOSED METHODOLOGY

In the proposed method, the content based recommendation system, Collaborative based recommendation system and hybrid recommendation system are used in the proposed method. The past data has been used to build the movies recommendation systems. This proposes that a rating relying on coordinates of the training set values is applied to the new phase. Computing the interval between the initial point and each point taken from the training dataset is the initial step. There are different ways to measure this distance, including different kind of distance such as Euclidean distance, Manhattan Distance and Hamming Distance. The three mentioned distance calculated using below equations. The very common purpose where recommender system is applied are OTT platforms, search engines, articles, music, videos etc. during this work we tend to propose a Collaborative approach-based Movie Recommendation system. We tend to propose economic healthcare associates during this paper the algorithmic rule of the Film Recommendation supported improved CNN strategy that measures simpler advisory system accuracy. the maximum inner circles, as well as the basic inner strategies are used. The exception to this is the projected results, which use algorithms to check for (supposedly) involvement. The performance results show that the projected strategies improve additional accuracy of the Movie recommendation system than the other strategies employed in this experiment.

3.1 Proposed architecture

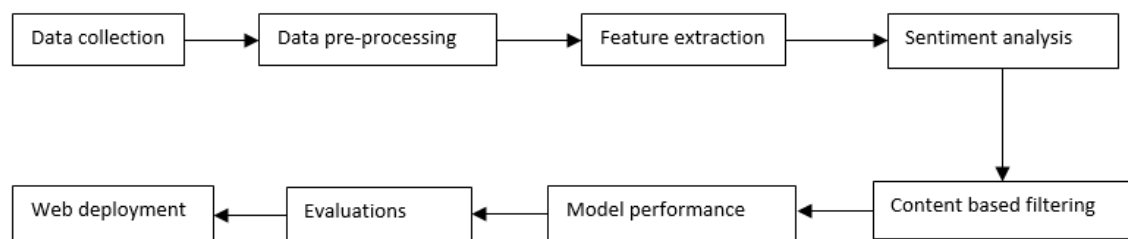


Fig 1. Proposed architecture

3.2 Proposed algorithm

Algorithm: A Knowledge-Based Recommendation System That Includes Sentiment Analysis and Deep Learning

Inputs: 2016.csv,2017.csv,2018.csv, prediction models M

Output: Recommender system results,

1 Start

2 Input feedback dataset

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3 Pre-processing
4 Extract features from training set()
5 For each model m in M
6 Train the model m
7 End For
8 For each model m in M
9 Use model for testing
10 Evaluate
11 Display results
12 End For
13 End
14 return R

```

Algorithm1 proposed algorithm

Algorithm 1 takes dataset and threshold value as inputs. It has an iterative process to collect all features from all attributes. Then it takes all features and starts another iterative process to know the features that satisfy given threshold. It divides the dataset into training and testing data with 80:20 ratio. Then it reuses the algorithm to obtain most relevant features for recommendation. Afterwards, there is an iterative process that uses different ML and CNN models to analyse recommendation system. Each model is evaluated with different performance metrics. Each model generates its own confusion matrix that is used to compute precision, recall, F1-score and accuracy. The algorithm provides the social media misleading prediction results and also performance statistics.

3.3 Performance Evaluation Metrics

Confusion matrix is the basis for deriving performance evaluation metrics in many ML based problems. Confusion matrix is widely used as explored in [2], [3], [7] and [10]. It has two correctly predicted cases (TP and TN) and two incorrect predictions such as FP and FN.

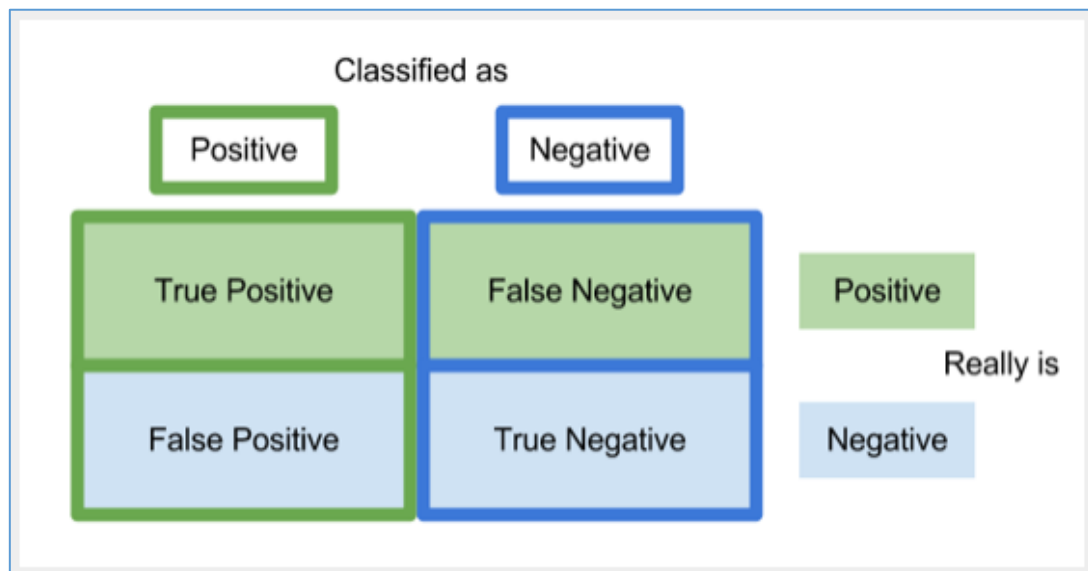


Figure 2: Confusion matrix model

As presented in Figure 3, different cases in the confusion matrix are used to arrive at the performance measures. The performance metrics are expressed in Eq. (4) to Eq. (7).

$$\text{Precision} = \frac{TP}{TP+FP} \quad (4)$$

$$\text{Recall} = \frac{TP}{TP+FN} \quad (5)$$

$$\text{F1-measure} = 2 * \frac{(\text{precision} * \text{recall})}{(\text{precision} + \text{recall})} \quad (6)$$

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad (7)$$

These metrics result a value between 0 and 1 reflecting lowest and highest possible performance. Higher value refers to better performance.

4. DATASET DESCRIPTION

The **IMDb Movie Reviews** dataset is a binary sentiment analysis dataset consisting of 50,000 reviews from the Internet Movie Database (IMDb) labeled as positive or negative. The dataset contains an even number of positive and negative reviews. Only highly polarizing reviews are considered. A negative review has a score ≤ 4 out of 10, and a positive review has a score ≥ 7 out of 10. No more than 30 reviews are included per movie. The dataset contains additional unlabeled data. These files contain metadata for all 45,000 movies listed in the Full MovieLens Dataset. The dataset consists of movies released on or before July 2017. Data points include cast, crew, plot keywords, budget, revenue, posters, release dates, languages, production companies, countries, TMDB vote counts and vote averages.

This dataset also has files containing 26 million ratings from 270,000 users for all 45,000 movies. Ratings are on a scale of 1-5 and have been obtained from the official GroupLens website. This dataset consists of the following files: movies_metadata.csv: The main Movies Metadata file. Contains information on 45,000 movies featured in the Full MovieLens dataset. Features include posters, backdrops, budget, revenue, release dates, languages, production countries and companies. keywords.csv: Contains the movie plot keywords for our MovieLens movies. Available in the form of a stringified JSON Object.

credits.csv: Consists of Cast and Crew Information for all our movies. Available in the form of a stringified JSON Object.

links.csv: The file that contains the TMDB and IMDb IDs of all the movies featured in the Full MovieLens dataset.

links_small.csv: Contains the TMDB and IMDb IDs of a small subset of 9,000 movies of the Full Dataset.

ratings_small.csv: The subset of 100,000 ratings from 700 users on 9,000 movies.

The Full MovieLens Dataset consisting of 26 million ratings and 750,000 tag applications from 270,000 users on all the 45,000 movies in this dataset can be accessed [here](#)

5. RESULTS AND DISCUSSION

This section presents results of experiments. The empirical study is made in terms of Social media misleading prediction observations and performance evaluation of the proposed method. The results of the proposed method are compared against existing feature selection models along with underlying prediction models. Multinomial and KNN are the ML models and CNN used for prediction.

Model name	accuracy
MultinomialNB	97.2
KNN	97.54
CNN	99.0265

Table 1 Model accuracy performance table

As presented in table 1, ML are used for prediction of Social media misleading information. Accuracy of different models are compared with traditional methods employed. There is significant performance improvement when proposed method is employed. Each method showed improved accuracy when compared with the models used in traditional methods

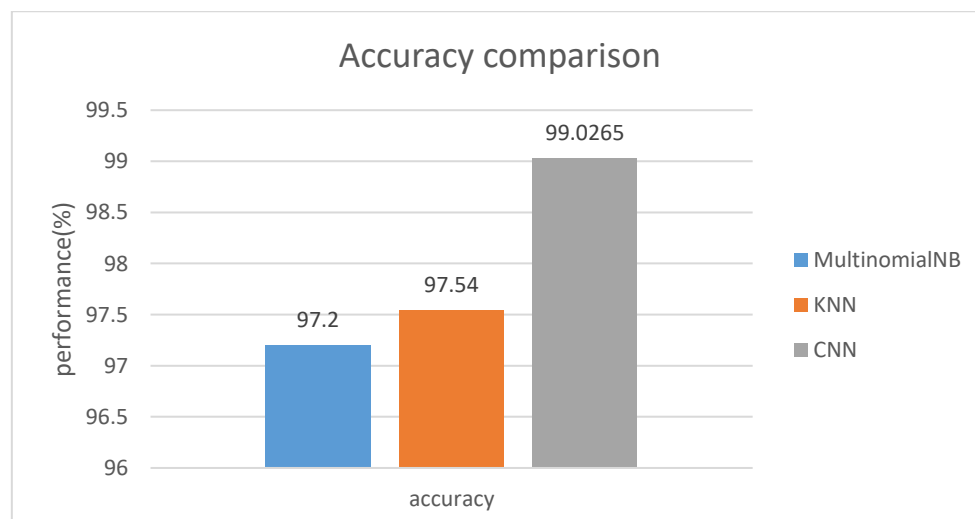


Fig 3 Model accuracy comparison graph

As presented in Figure 3, ML and CNN methods are used for prediction of Social media misleading information. Accuracy of different models are compared with other employed algorithms. There is significant performance improvement when feature selection is employed. MultinomialNB showed accuracy as 97.2%, KNN showed accuracy of 97.54% and the CNN model had showed higher accuracy of 99.025%.

6. CONCLUSION

In this research paper, we have addressed the limitations of CNN based document modeling approach as well as CNN and RNN based text representation approach. We have proposed a novel and powerful DNN text analysis model stacking Capsule Networks and Bi-directional RNN to generate the textual representation of users' and items' reviews integrated with PMF to improve recommendation performance. Experiments results have proved that exploiting ratings, items' and users' reviews have improved rating prediction accuracy and precision and recall of top-n recommendations. It can also be concluded that the proposed model, "CapsMF", performs better on more massive datasets as compared to smaller datasets. Both the users and items reviews have been considered to build the separate deep neural network for text analysis. Hence, it has resulted in better recommendations to the users and also solves the cold-start problem in recommender systems. There are still certain limitations that come with Capsule Networks; one that has been observed while performing the experiments is that capsule networks take times in training. The advantage is that it takes fewer data points in training as compared to CNN. In future works, we would refine the deep neural network for text analysis with new deep learning technologies getting discovered for analysis of text for getting a better representation of the text. We would apply the proposed model in different recommendation datasets and scenarios such as social recommendations [3], joint-recommendation, group recommendation [33], etc. Other contextual information related to users and items such as images, tweets [10, 13], metadata about products can be integrated with collaborative based filtering technique to enhance the personalized recommendations.

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