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Information retrieval models in Neural Networks Framework: A survey

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ABSTRACT

Information retrieval using neural networks both as shallow or deep neural networks is an emerging field. This paper presents a survey on neural network models used at various stages of information retrieval. Information Retrieval is taking a new dimension everyday with the abundant information available in World Wide Web and World Wide Web is acting as universal information repository of human knowledge. The paper focuses on text information retrieval and emphasizes the importance of context-based information retrieval.

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1. Introduction

Information Retrieval (IR) involves information storage, representation and retrieval of relevant information based on the needs of the user. Every stage of information retrieval is crucial and plays an important role in efficient retrieval. Though Information retrieval has a set of standard approaches and models to deal with, the emergence of intelligent and efficient models is the need of the hour thanks to World Wide Web has become a major source of human based knowledge. Information retrieval happens in multiple ways. Giving a text query, choosing one of query suggestions given by the search system, giving voice query or image are different forms to get the information needed. Sometimes, the user query may not be explicit or direct. Text information retrieval is the most common form. Some applications of text information retrieval are: News articles retrieval, research articles retrieval and patents information retrieval. The scope of information retrieval becomes larger and larger because of the users from varied perspectives. Bhaskar Mitra and Nick Craswell [1] propose the following set of attributes that must be considered by a good IR model.

- Semantic understanding
- Robustness to rare inputs
- Robustness to corpus variance
- Robustness to variable length inputs
- Robustness to errors in input
- Sensitivity to context and
- Efficiency

The IR is taking a different turn with the inclusion of context-natural language processing. Information Retrieval framework is depicted in Fig. 1.

We can focus on Neural Network models in two perspectives. Neural Network Models used at various phases of IR and Neural Network Models used at all phases of IR. For example, Tang et al. [3] used different forms of neural networks at different stages of Document Modelling. Convolutional Neural Networks and/or Long Short-term Memory are used for sentence composition and forward and backward gated recurrent neural networks are used for document composition.

Cunningham et al. [4] discusses the opportunities for Neural Networks implementation in different processes of Information Retrieval: Query Formulation, Query Refinement, Inference Networks that rank relevant documents, Document Clustering, Document Filtering, Clustering of Query results etc.

2. Neural Networks for IR tasks

This paper focusses on the involvement of Neural Networks in IR phases for the last two decades. The neural networks considered here are trained in supervised, unsupervised and semi-supervised methods. As the literature involves several neural network models used in combination to achieve efficiency on the whole, the classification or taxonomy of models is cumbersome. We limit our scope to the study of various models and the presentation of key idea of the models.

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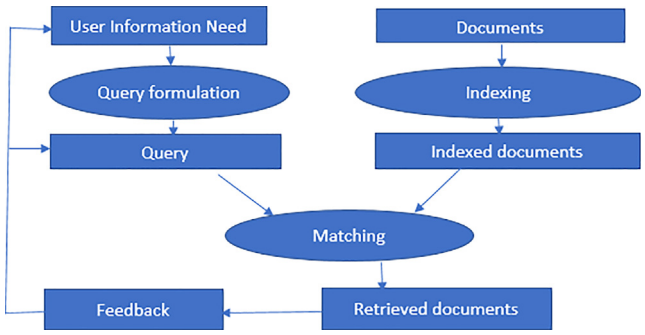

Fig. 1. Basic information retrieval processes []. adapted from: [2]

Though the neural/machine learning models are studied in 1990's, word2vec model proposed by Mikolov et al. for estimating word embedding and the availability of code and training data has inspired many researchers to focus on Neural models of IR. The surge of Deep Learning and its success in the areas like Computer Vision is also another reason for the raising interest in Neural models of IR. The strength of Neural Networks is that they can work from raw input data. Different forms of Neural Networks considered for IR tasks are: Feed-forward Neural networks with back-propagation of error, Auto-encoder Neural Network, Convolutional Neural Networks, Recurrent Neural Networks, and Deep Neural Networks.

Traditional IR uses lexical matching and the modern IR uses semantic matching. Though semantic matching is robust, it's costlier than lexical matching. Deep Structured Semantic Model (DSSM) is developed based on Deep Neural Networks and some other type of networks. This model waspropose by Huang et al. for ad-hocinformation retrieval [5]. They propose word hashing method to deal with large vocabularies and large-scale training. This DSSM was extended by Shen et al. in the form of Convolutional Deep Structured Semantic Model (C- DSSM). In addition to the functionalities of DSSM, C-DSSM uses max pooling layer that extracts important local features and forms a fixed length global feature vector [6]. Shen et al. [7] also proposed a Convolutional Latent Semantic Model (CLSM) as an extension to DSSM. CLSM is able to capture the contextual information where as DSSM and C-DSSM fail to do so [8,9]. Query Auto Completion can be done by generating prefix-suffix pairs from search query logs and training and ranking using CLSM [10].

Recurrent Neural Networks can be used to extract user interests and their behavioural patterns based on the long users' actions. These models are widely adopted in Sponsored Search [8].

Palangi et al. [11] developed a recurrent neural network model with long short-term memory cells to model sentence embedding. Through this model, the semantic representation of the whole sentence can be developed.

Convolutional Neural networks are widely used for image classification in the area of Digital Image Processing. The same idea is adopted in IR in sentence classification and prefix-suffix mapping.

Almost all the neural network models for IR use word embeddings. Some models use word embeddings explicitly and some models use them implicitly.

The probabilistic IR uses two important parameters: the probability of relevance of a document and the probability of irrelevance of a document [12]. Neural Networks are an alternative to probabilistic models.

Mokris and Skovajkov [13] modelled the information retrieval of documents in Slovak language. The model is conceptually simple and was proven efficient through the MATLAB experiments with limited number of documents. They considered three layer Informational Retrieval System. See Fig. 2 the corresponding Neural Information Retrieval System is depicted in Fig. 3. First Neural Network is a multi-layer perceptron with back propagation and contains three layers, input, hidden and output layers. In the second Neural Network, the input layer is considered with keywords as input and an output layer with documents. The hidden layer is not considered.

Roberson and Dankel [14] proposed Morphological Neural Network Information Retrieval (MNNIR) Model to improve the performance of IR systems. Morphological Neural Net- work is a variant of Artificial Neural networks and is a lattice algebra-based version of Artificial Neural Networks. MNNIR is built on Vector Model and uses the query vector to dynamically construct the network to rank the documents.

Mohan et al. [15] applied Deep Neural Networks to model the relevance of document's text to the given query in bio-medical literature. They show that their model out performs with the underspecified queries and term mismatch problems (Table 1).

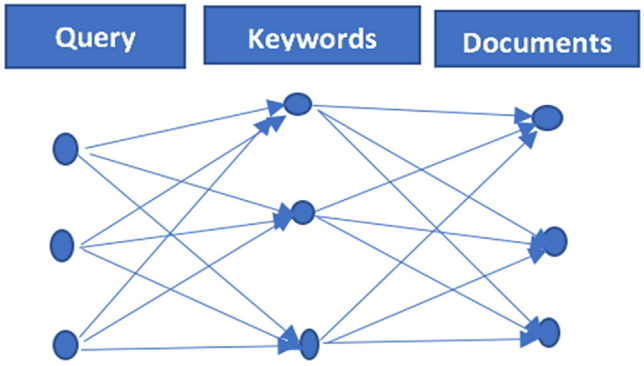

Fig. 2. Three layer IR system.

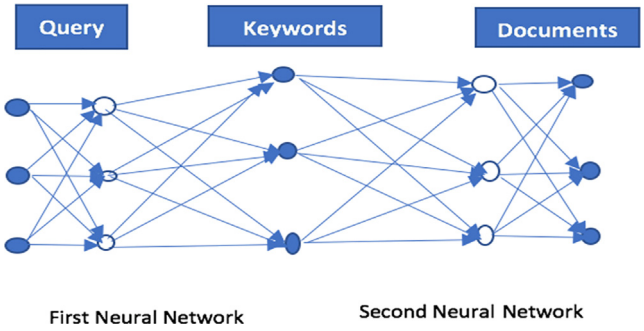

Fig. 3. Neural information retrieval model.

Table 1
Various neural network models.

IR task	Neural Network Models
Ad-hoc retrieval	BWESG, GLM, sMitra et al. (2016), NLTM, DSSM, CLSM
Conversational Agents	DL2R
Proactive Search	Luukkonen et al. (2016)
Query Auto-completion	Mitra (2015); Mitra and Craswell (2015)
Question Answering	BLSTM, CDNN, DFNN, DL2R
Query Suggestion	Sordoni et al. (2015)
Recommendation	TDSSM (song et al.2016)
Sponsored Search	Zhang et al. (2016a)
Temporal IR	Stacked Multilayer Perceptron Networks (Kanhabua et al. (2016))
Context extraction	Manotumruka et al. (2016)

Neural ranking models lie at the core of IR research. Many different techniques were used for ranking from heuristic techniques and probabilistic methods to the present machine learning methods. With the advancement of Deep Learning, people have focused ion applying deep and shallow networks to ranking models. The first successful neural ranking model is DSSM applied for ad-hoc information retrieval. Later DeepMatch was proposed to work with community-based question answering (CQA) and micro-blog (Eg. Twitter) matching tasks [16]. Some neural ranking models that focused on short-text matching are a variant of DSSM, MatchPyramid, ARC I, and ARC II. Still, Neural ranking models for IR didn't thrive a break-through when compared to the models of Computer Vision and Natural Language Processing [17].

Liu et al. [18] used multi-tasking deep neural networks to learn representations of multiple tasks. It combines query classification and ranking tasks. They state that their model out performs classification and ranking tasks and this general model can be extended to sentiment analysis and paraphrase extraction in the documents.

3. Contextual information retrieval

Limbu et al. [19] proposed a framework architecture for Contextual Information Retrieval with regard to WWW. See Fig. 4.

Profile collector Model and Context Manager model are two important elements of the framework. The Profile Collector model that works in association with user interface unit has two agents: Adaptive agent and Preference Agent. Adaptive agent captures the user behaviour and based on this the Preference agent interacts with Context Knowledge Agent and provides the user the search suggestions.

The Context Manager Model comprises four agents namely Context crawler agent, Knowledge agent, query process agent and Integration agent. Context crawler agent's job is to fetch the contextual profiles of the user. Context Knowledge Agent processes the contextual profiles and Query Process agent forms/rephrases the query. The total contextual information retrieval is supported by Integration agent.

We assume that Neural Networks with Backpropagation of error is suitable for learning the user behaviour to extract the context. Our project focuses on answer to question kind of information retrieval rather than ad-hoc retrieval. The scope of user behaviour modelling would be large in case of WWW. So using Neural Networks for learning user behaviour in the above model would be very costly. as the users size would be in millions. In our project, we deal with comparatively less size of user data, using Neural Networks would become efficient and accurate Shen et al. [7] proposed Convolutional Latent Semantic Model (CLSM) that works as an extension to DSSM to capture the contextual features in the query and the documents.

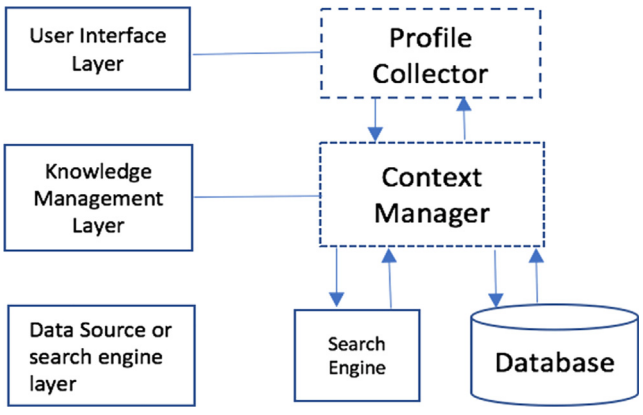

Fig. 4. Contextual information Retrieval framework.

4. Conclusion

We studied and presented the Neural Network Models used in all and different phases of Information retrieval query auto completion to ranking of relevant documents. Very few models focus on working with contextual features of information retrieval. Though there is a huge attention on Neural Network models of IR since 2010, there is a large scope of research in this area as we need to deal with large data and large training samples. Contextual Information Retrieval is still at its infancy which needs focus and attention from the research community. We studied various models as part of the first author's research project that works on extracting news articles from a repository based on the context imposed either by the query or based on the user.

CRediT authorship contribution statement

Komala Anamalamudi: Conceptualization, Methodology, Software, Visualization, Writing - original draft. **Y.C.A. Padmanabha Reddy:** Data curation, Supervision, Validation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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