

# Neural Ranking Models with Weak Supervision\*

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## EXTENDED ABSTRACT

Learning state-of-the-art deep neural network models requires a large amounts of labeled data, which is not always readily available and can be expensive to obtain. To circumvent the lack of human-labeled training examples, unsupervised learning methods aim to model the underlying data distribution, thus learning powerful feature representations of the input data, which can be helpful for building more accurate discriminative models especially when little or even no supervised data is available.

A large group of unsupervised neural models seeks to exploit the implicit internal structure of the input data, which in turn requires customized formulation of the training objective (loss function), targeted network architectures and often non-trivial training setups. Despite the advances in computer vision, speech recognition, and NLP tasks using unsupervised deep neural networks, such advances have not been observed in core information retrieval (IR) problems, such as ranking. A plausible explanation is the complexity of the ranking problem in IR, in the sense that it is not obvious how to learn a ranking model from queries and documents when no supervision in form of the relevance information is available.

To overcome this issue, in this paper, we propose to leverage large amounts of unsupervised data to infer “noisy” or “weak” labels and use that signal for learning supervised models as if we had the ground truth labels. In particular, we use classic unsupervised IR models as a *weak supervision* signal for training deep neural ranking models. Weak supervision here refers to a learning approach that creates its own training data by heuristically retrieving documents for a large query set. This training data is created automatically, and thus it is possible to generate billions of training instances with almost no cost. As training deep neural networks is an exceptionally data hungry process, the idea of pre-training on massive amount of weakly supervised data and then fine-tuning the model using a small amount of supervised data could improve the performance.

The main aim of this paper is to *study the impact of weak supervision on neural ranking models*, which we break down into the following concrete research questions:

**RQ1** *Can labels from an unsupervised IR model such as BM25 be used as weak supervision signal to train an effective neural ranker?*

**RQ2** *What input representation and learning objective is most suitable for learning in such a setting?*

**RQ3** *Can a supervised learning model benefit from a weak supervision step, especially in cases when labeled data is limited?*

We examine various neural ranking models with different ranking architectures and objectives, i.e., point-wise and pair-wise, as well as different input representations, from encoding query-document pairs into dense/sparse vectors to learning query/document embedding representations. The models are trained on billions of training examples that are annotated by BM25 as the weak supervision signal. Interestingly, we observe that using just training data that are annotated by BM25 as the weak annotator, we can outperform BM25 itself on the test data.

Based on our analysis, the achieved performance is generally indebted to three main factors:

- Defining an objective function that aims to learn the ranking instead of calibrated scoring, which relaxes the network from fitting to the imperfections in the weakly supervised training data.
- Letting the neural networks learn optimal query/document representations instead of feeding them with a representation based on predefined features. This is a key requirement to maximize the benefits from deep learning models with weak supervision as it enables them to generalize better.
- The weak supervision setting makes it possible to generate massive amount of training data with almost no cost and train the data hungry neural network model where such amount of training data is not available.

We further thoroughly analyse the behavior of models to understand what they learn, what is the relationship among different models, and how much training data is needed to go beyond the weak supervision signal. We also study if employing deep neural networks may help in different situations. Finally, we examine the scenario of using the network trained on a weak supervision signal as a pre-training step. We demonstrate that, in the ranking problem, the performance of deep neural networks trained on a limited amount of supervised data significantly improves when they are initialized from a model pre-trained on weakly labeled data.

Our results have broad impact as the proposal to use unsupervised traditional methods as weak supervision signals is applicable to variety of IR tasks, such as filtering or classification, without the need for supervised data. More generally, our approach unifies the classic IR models with currently emerging data-driven approaches in an elegant way.

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## REFERENCES

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