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Semantic Question Matching with Deep Learning

Nikhil Dandekar, works at Quora
Posted Feb 14, 2017

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In order to build a high-quality knowledge base, it's important that we ensure each unique question exists on Quora only once. Writers shouldn't have to write the same answer to multiple versions of the same question, and readers should be able to find a single canonical page with the question they're looking for. For example, we'd consider questions like "What are the best ways to lose weight?", "How can a person reduce weight?", and "What are effective weight loss plans?" to be *duplicate questions* because they all have the same intent. To prevent duplicate questions from existing on Quora, we've developed machine learning and natural language processing systems to automatically identify when questions with the same intent have been asked multiple times.

We recently released a public dataset of duplicate questions that can be used to train duplicate question detection models like the one we use at Quora. In this post, we'll give you a sense of what's possible with our duplicate question dataset by outlining a few deep learning explorations we pursued in a recent hack week.

We're also excited to announce a **meetup event for NLP and Machine Learning enthusiasts** that we'll be hosting at the Quora office in Mountain View, CA on the evening of **February 27**. We have a couple of exciting speakers lined up: Ben Hamner, co-founder and CTO of Kaggle will talk about "Kaggle Competitions and Reproducible Machine Learning", and Xavier Amatriain, VP of Engineering at Quora, will be giving a talk entitled "Machine Learning and NLP at Quora". If you're interested in attending, please apply to join here ↗.

Problem Definition

More formally, the duplicate detection problem can be defined as follows: given a pair of questions $q1$ and $q2$, train a model that learns the function:

$f(q1, q2) \rightarrow 0$ or 1

where 1 represents that $q1$ and $q2$ have the same intent and 0 otherwise.

A simple duplicate detection approach is a word-based comparison. For example, we can use standard information retrieval measures like tfidf ↗ - ↗ or BM25 ↗ to find the word-based similarity between the two questions, then classify question pairs with similarity scores above a certain threshold as duplicates. But, if we want to detect duplicates at a more intent-based, semantic level, we need more intelligent approaches than these simple measures. In fact, there is active ongoing research in the Natural Language Processing community on this very problem [1-3].

Our Approaches

Our current production model for solving this problem is a random forest model with tens of handcrafted features, including the cosine similarity of the average of the word2vec embeddings of tokens, the number of common words, the number of common topics labeled on the questions, and the part-of-speech tags of the words.

Inspired by recent advances in the deep learning research community, we recently experimented with three end-to-end deep learning solutions to the duplicate detection problem. Because each of these approaches was an end-to-end deep learning solution, we were able to save time by avoiding iterative, and often computationally complex feature

were able to save time by avoiding iterative, and often computationally complex feature engineering.

Our first approach was an in-house deep architecture that used Recurrent Neural Networks (RNNs). More specifically, we used the Long Short Term Memory network (LSTM) variant of RNNs, which are better at capturing long-term dependencies. We trained our own word embeddings using Quora's text corpus, combined them to generate question embeddings for the two questions, and then fed those question embeddings into a representation layer. We then concatenated the two vector representation outputs from the representation layers and fed the concatenated vector into a dense layer to produce the final classification result. Below is a visual representation of our first approach:
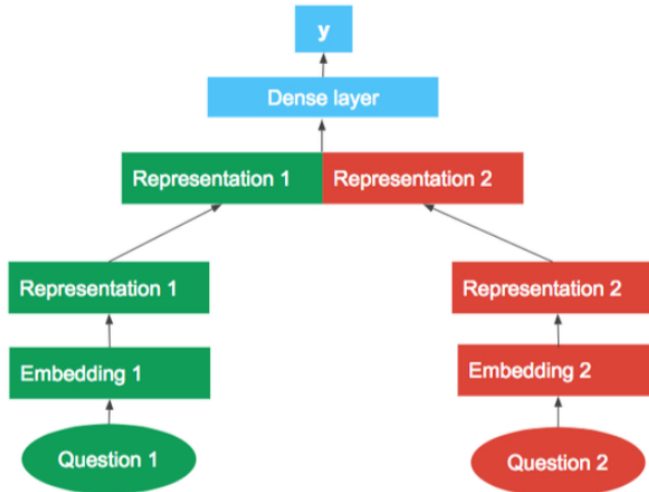

Figure 1: Architecture of approach 1, "LSTM with concatenation"

In our second exploration, we implemented the approach of Tai, Socher empirically-motivated handcrafted features: (1) the distance, calculated as the sum of squares of the difference of the two vectors, and (2) the "angle", calculated as an element-wise multiplication of the two vector representations (denoted 0). A neural network using the distance and angle as the two input neurons was then stacked on top, as shown below:two, and Manning [1] (footnote a). Similar to the previous approach, this too was an LSTM network, but rather than concatenating information from the two vector representations, this approach used
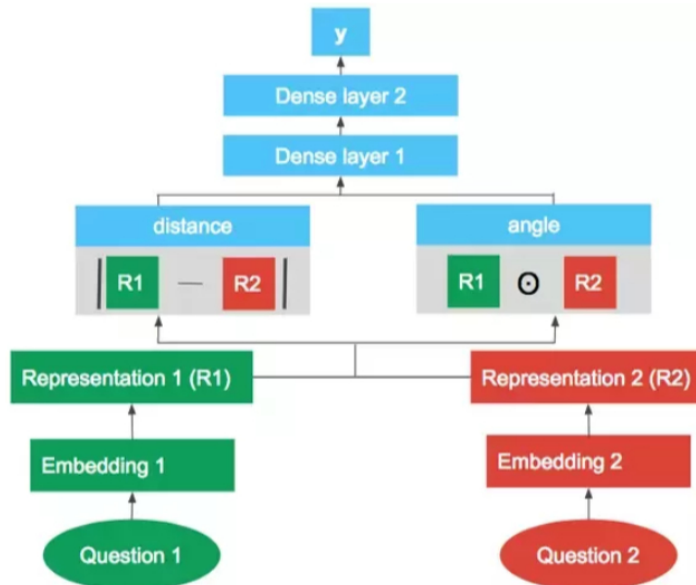

Figure 2: Architecture of approach 2, "LSTM with distance and angle"

Finally, we tried an attention-based approach from Google Research [4] that combined neural network attention with token alignment, commonly used in machine translation. The most prominent advantage of this approach, relative to other attention-based approaches, was the small number of parameters. Similar to the previous two approaches, this model represents each token from the question with a word embedding. The process, shown in Figure 3, trained an attention model (soft alignment) for all pairs of words in the two questions, compared aligned phrases, and finally aggregated comparisons to get classification result.
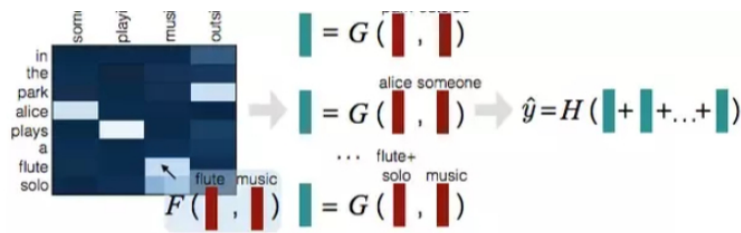
Figure 3: Overview of approach 3, "Decomposable attention" (from [4])

Here is how these three approaches compared to each other on our test data:

	LSTM with concatenation	LSTM with distance and angle	Decomposable attention
Accuracy	0.87	0.87	0.86
Precision	0.88	0.83	0.81
Recall	0.86	0.94	0.95
f1 score	0.87	0.88	0.87

In the future, we plan to experiment with more complex, deeper architectures as well as ensembles of different approaches, but we hope these examples illustrate several different approaches to the duplicate question detection problem.

We're excited to connect with fellow members of the NLP and ML communities at our meetup on February 27th. You can learn more and request an invite here ↗.

Finally, if you're interested in working on NLP and ML problems at Quora, we're hiring! Check out our careers page for all of our open positions.

Acknowledgements

This exploration was a collaboration between members of our engineering and data science teams: Hilfi Alkaff, Shuo Chang, Kornél Csernai, Nikhil Dandekar, and Lili Jiang.

References

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Footnote

a. The original paper proposes a tree-LSTM approach, where it parses the structure of input sentences based on POS tags. In practice, because of speed reasons, we didn't use the tree-LSTM approach but instead borrowed their architecture for a simple LSTM model.

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Tomorrow Wang
Feb 14, 2017 · 12 upvotes

We got accuracy at 88.17% on our test set. You can find the details about our model at https://arxiv.org/pdf/1702.03814... ↗, and our dataset partition can be find at Quora_question_pair_partition.zip ↗

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Dima Korolev
Feb 19, 2017 · 1 upvote

In the comparison table, LSTM with concatenation and LSTM with distance and angle appear to trade precision and recall. How did you calibrate the threshold for those?

A more generic question would be: with algorithms of so different outputs, why compare f1-s if you could look at the area under th...(more)

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Kiran Kannar
Mar 10, 2017 · 1 upvote

Can you explain the intuition behind concatenation of the two representations in the first architecture?

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Michael Dixon
Feb 16, 2017 · 2 upvotes

Will question merges made by machine learning tools still be able to be challenged and unmerged by Quora members using simple common sense? By "challenged" I am referring to appeal through Quora moderators.

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Eric Drummond
Feb 21, 2017 · 1 upvote

If they are clever, humans will look at questions that get merged by bot, and unmerged by humans - great feedback for ML.
Multiple unmerges should have priority.

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Achilleas Vortselas
Feb 17, 2017

How do you define Accuracy, Precision, Recall and the f1 score?

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Harshit Khatri
Feb 20, 2017 · 1 upvote from Achilleas Vortselas

As you would for any binary classification problem.

See Precision and recall - Wikipedia ⧉

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