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Literary Review

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Natural Language Understanding

Abstract

This document is a review of relevant existing literature for building different components of a Question Answering System

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# Literature Review

## Introduction

Our team (Naturally Speaking) is interested in exploring the idea of building a domain specific question answering system (Q & A) that utilizes a knowledge graph to store and retrieve information specific to that domain. Our team comprising (Ethan Nguyen, Mohan Rangarajan, Vu Pham) researched a set of papers around two areas

1. Q & A – focusing on effective representation of the question posed and utilizing reading comprehension on retrieved paragraphs to determine the associated response i.e. we wanted to capture the intent of the question by utilizing contextual embedding and attention mechanisms. In addition, we wanted to also use the transformer decoder to improve the reading comprehension and thereby extract the appropriate response to the question
2. Integration between Q & A and the knowledge graph to efficiently retrieve responses from the knowledge graph

In each category, we have outlined the papers chosen, the motivation behind selecting the paper and what we anticipate leveraging in our final project from the paper.



Figure : Initial idea for the project

## Motivation

This section outlines why we chose the different papers as part of our literary review.

Attention is All You Need has the seminal work on utilizing attention mechanism and not rely on the sequential nature of the recurrence thereby allowing parallelization. If our Q & A system responses required us to train a large domain specific corpus, then employing this approach would reduce the training time required.

When the context (i.e. in the paragraph or in the knowledge graph from which to retrieve answers) does not have the answers, the system must rely on providing approximate answers or respond back with a “negative” response (like “I am sorry I don’t have the answer etc.”). While this may be appropriate in some scenarios, the user experience may be enhanced if we are able to elicit more clarity on the user’s intent (with a response like “Let me clarify if this is your question”). TransferTransfo: A Transfer Learning Approach for Neural Network Based Conversational Agents proposes a “generative” model for responding to user’s questions by transferring learning from a relevant domain context in conjunction with dialog history between the user and the Q & A system.

NLP tasks like Domain specific Question Answering may not have enough data. In those scenarios, contextual embeddings obtained from models pre-trained on large corpora may help mitigate issues. The approach outlined in SpanBERT: Improving Pre-training by Representing and Predicting Spans extends the original Bi-directional Encoder Representation for Transformers (BERT) and has better performance especially in selecting answer spans in Question Answering task.

#### One major issue for conversation systems is their propensity to select the response with greatest likelihood, a consensus response of the humans represented in the training data. Outputs are frequently vague or non-committal and can be wildly inconsistent lack human identity. Personalizing Dialogue Agents: I have a dog, do you have pets too? proposes an encoded persona in distributed embeddings that capture individual characteristics such as background information and speaking style

There are lots of research in question answer over knowledge graphs with many complex systems that claim state of the art performance. Strong Baselines for Simple Question Answering over Knowledge Graphs with and without Neural Networks helps provide a rigorous analysis and compares to complex systems to quantify performance gain.

In general, single-relation or simple question answering is still far from perfect because the predicate of a question can be expressed in many different ways, and the question's subject (entity mentioned) can also be ambiguity by the context, typo, spaces. These problems at best hinder the matching of the pair (pattern/mention) from the question to the triple (head, relation, tail) in the knowledge graph and at worse cause the system to return the wrong answer. These four papers [HHH: An Online Medical Chatbot System based on Knowledge Graph and Hierarchical Bi Directional Attention](https://arxiv.org/pdf/2002.03140.pdf) , [Semantic Parsing for Single-Relation Question Answering](https://www.aclweb.org/anthology/P14-2105/), [Simple Question Answering by Attentive Convolutional Neural Network](https://www.aclweb.org/anthology/C16-1164/), and [Knowledge Graph Embedding Based Question Answering](https://dl.acm.org/doi/10.1145/3289600.3290956) present various approaches on how to find the best answer from KG with different paraphrases or ambiguous subjects. Furthermore, the HHH: An Online Medical Chatbot System based on Knowledge Graph and Hierarchical Bi Directional Attention paper explores the inner working of a real-world application of task-oriented QA system with knowledge graph and its system architecture with various NLP components.

## Problem/Task Definition

Sequential nature of the RNNs and GRUs prevent parallelization of computation required to accelerate the training process in preparation for an NLP task like language modeling and machine translation. Attention is All You Need examines the parallelization aspect that is especially important when there are a lot of examples and memory limitations that constrain batching across examples.

Recurrent neural network based conversational agents with enough capacity and access to large data sets still have a tendency to produce generic responses, inconsistent outputs. In addition, these agents have difficulty in factoring more than the last dialogue utterance (the actual words communicated) as part of the response. TransferTransfo: A Transfer Learning Approach for Neural Network Based Conversational Agents attempts to address these issues by generating responses based on past dialogue history and persona profile of the speaker.

Chatbots for social dialogue tend to have similar problems which raised by the TransferTransfo: A Transfer Learning Approach for Neural Network Based Conversational Agents paper, the responses are too generic and irrelevant while lacking context and consistent persona. Authors of Personalizing Dialogue Agents: I have a dog, do you have pets too? propose using model’s condition on profile information and interlocutors’ information to make the dialogue more human like.

Answers required for NLP tasks frequently may involve reasoning that requires drawing inferences between two or more spans of text. Unlike approaches that propose increasing the size of the data or model size, the pre-training method used in SpanBERT: Improving Pre-training by Representing and Predicting Spans focuses on the training task and objective that is designed to better (a) represent the question and (b) better predict spans of text that will represent answers.

Answers Baseline for Q&A with knowledge graph has not been explored adequately and it is unclear how much Neural Networks techniques actually help. Strong Baselines for Simple Question Answering over Knowledge Graphs with and without Neural Networks authors seek to establish strong baseline to objectively quantify the contribution of various DL techniques to many steps of Q&A problem which include entity detection, entity linking, relation prediction and evidence combination.

A knowledge-based system holds clear advantages in providing targeted responses to well-defined questions and thus is a convenient and reliable approach in implementing a question answering system in knowledge centric domains such as medical fields. However, a knowledge-based system can sometimes be too rigid in a conversational context. HHH: An Online Medical Chatbot System based on Knowledge Graph and Hierarchical Bi Directional Attention authors propose a neural network model which provides a more flexible way for various situations where questions are not matched in knowledge-based system.

A simple semantic parser tailored to single-relation questions, powered by advanced semantic similarity models to handle the paraphrase issue is used in Semantic Parsing for Single-Relation Question Answering to find best match answer from the KB. The paper’s authors propose a simple semantic parser tailored to single-relation questions, powered by advanced semantic similarity models to handle the paraphrase issue is used to find best match answer from the KB

Another novel approach, proposed by the authors of Simple Question Answering by Attentive Convolutional Neural Network paper, involves character-level and word-level convolutional neural networks to improve the accuracy when matching single subject and predicate questions (simple questions) with facts from Freebase.

Finally, research in Knowledge Graph Embedding Based Question Answering proposes using word embedding, neural networks, and a special distant metric function to find the closest KG triple to the relation/mention vectors from the question. This research proposes a two-step process: 1. separate a question into a relation pattern and an entity mention, then 2. use a semantic similarity model based on a twin CNN to find the best match of the pattern/mention from the KG

## Paper Summary

Attention is All You Need proposes relying entirely on “attention” mechanisms. By using multi-head attention in conjunction with positional encoding, the paper takes advantage of order of the sequence in the input, dependencies within the input and dependencies between inputs/outputs. Multi-head attention also enables the model to attend to information from different representation subspaces at different positions. A position wise feed-forward network is used in conjunction with the attention sub-layer. The model comprises an encoder stack and a decoder stack with each stack having a self-attention and a feed-forward network. The decoder stack has an additional attention layer that allows the decoder to attend all positions in the input sequence.

TransferTransfo: A Transfer Learning Approach for Neural Network Based Conversational Agents utilizes a masked, multi-attention decoder-only transformer (based on Generative Pretrained Transformer). In addition to the user’s question, the model uses persona profile of the user and learned positional embeddings pretrained on the BooksCorpus dataset. The input representation utilizes a combination of utterance embedding, dialog state embedding and positional embeddings. For each user ‘s utterance, the sequence of input tokens for the model is concatenated with all the sentences in the user’s persona profile and the history of the dialog’s 3 -5 previous utterances. A multi-task learning approach is used by optimizing for a combination of next utterance classification loss and Language Modeling loss. Responses were generated using a beam search with sampling.

SpanBERT: Improving Pre-training by Representing and Predicting Spans proposes two key differences from BERT for pre-training – masking scheme and training objective. Random contiguous spans are masked (rather than individual tokens) and a “span-boundary” objective” is used. In-lieu of predicting individual masked tokens, the model learns to predict the entire masked span from the observed tokens within its boundary. Also, SpanBERT does not utilize the Next Sentence Prediction (NSP) objective in BERT. Only single segments of text are sampled from the corpus. SpanBERT exceeds BERT F1 score on SQuAD 1.1. and SQuAD 2.0 by 3.3% and 5.4%.

Personalizing Dialogue Agents: I have a dog, do you have pets too? introduces the PERSONACHAT dataset which consists of crowd-sourced dialogues where each participant plays the part of an assigned persona; while each persona has a word-distinct paraphrase. The authors test various ranking and generative models on the PERSONACHAT dataset, and show that models that have access to their own personas in addition to the state of the dialogue are scored as more consistent by annotators but not as more engaging. They also show that models trained on PERSONACHAT (with or without personas) are more engaging than models trained on dialogue from other resources (movies, Twitter). Hence, making the PERSONACHAT dataset is a useful training set for open ended conversation system.

On SIMPLEQUESTION dataset, Strong Baselines for Simple Question Answering over Knowledge Graphs with and without Neural Networks finds simple LSTMs and GRUs with few common heuristics yield accuracies that comparable with state-of-the-art techniques. They also show non deep learning techniques such as CRF and Logistic Regression perform reasonably well on entity detection and relation prediction. They conclude that some state-of-the-art NN architectures only improve modestly at the cost of significant complexity and heavy technical debt.

HHH: An Online Medical Chatbot System based on Knowledge Graph and Hierarchical Bi Directional Attention authors propose an online question and answer system for medical application. The hybrid system consists of a knowledge graph and a text similarity model to find the most similar question from a large QA dataset using hierarchical BiLSTM attention architecture. The text-similarity model is found to outperform MaLSTM and BERT due to the benefit of its attention layer and its embedding on the specific domain.

Semantic Parsing for Single-Relation Question Answering proposes a new semantic parsing framework based on twin (Siamese) CNN with maxpooling and sub-word hashing. A letter-trigram count vector from the input words is used to match relation patterns (predicate) and entity mentions (entity). The model runs on the PARALEX knowledge base. The letter-trigram vectors enable the model to handle out-of-vocab problem better and also outperform the Bag of Words representations. Experiments show this framework achieves higher F1 and Recall on the QA task than the previous work PARALEX.

To improve the simple QA problem, authors of Simple Question Answering by Attentive Convolutional Neural Network use an effective entity linker ( either passive where longest consecutive common subsequence is applied, or active where a BiLSTM\_CFR is applied ) to find the possible ( mention, pattern) pairs and , and then use a fact selection with one character-level CNN to find the entity that matches the mention, and one word-level CNN with attentive max-pooling to find if a predicate is a paraphrase of the pattern. The model runs on Freebase KG, and trains on SimpleQuestions question set. Their model shows better performance on the simple QA system as well as the predicate classification.

Using the embedding word representations for the KG, the research proposed in Knowledge Graph Embedding Based Question Answering can handle questions that have entities and predicates different from the ones in the training data by finding the closest entity and relation candidates. The embeddings also preserve the sentence structure and relation information which helps better predictions of predicate and entities from the KG. The model uses an attention-based BiLSTM to calculate the representations of the predicate and head entity. Instead of searching all the head entities in the KG which consumes time, a head entity detection model is used to select successive tokens in the question as the name of the head entity. A special distance function is used to find the final triple as the answer for the question. The model runs on two Freebase subsets FB2M, FB5M and the SimpleQuestions question set. Experiments show this model has better performance than all state-of-the-art method.

## Future Work

Attention is All You Need looks at performance of translation and generalization as applied to English constituency parsing. Other NLP tasks such as Question Answering using Q & A datasets or Dialogue systems have not been evaluated. Image, audio and video modalities have not been tried and may be useful especially when encountering a combination of modalities in the corpus. When long sequences are involved, the impact on computational performance can be evaluated. To do so, we can restrict self-attention to consider only a neighborhood of limited size in the input sequence centered around the respective output position.

Optimal settings and hyper parameters still need to be identified for the current transformer model chosen in TransferTransfo: A Transfer Learning Approach for Neural Network Based Conversational Agents. It will be interesting to test against other data sets than just the PERSONA-CHAT training set. Additional transformer models can be used for evaluation.

Modifications to the masking budget (currently set at 15% of the input tokens) and the potential impact on performance of the model proposed in SpanBERT: Improving Pre-training by Representing and Predicting Spans is an interesting candidate for further research. Also, the span boundary objective proposed can be further researched to examine the impact of utilizing information in the preceding token (not just the beginning of the span boundary) for predicting the next token in the span.

Looking forward, the authors of Personalizing Dialogue Agents: I have a dog, do you have pets too paper foresee human generated profiles such as PERSONACHAT dataset can be used to predict users’ profiles and guide goal-directed dialogue, which has wide application in business areas. They hope that the dataset will aid training agents that can ask questions about users’ profiles, remember the answers, and tailor them naturally in conversation.

Benefits of neural networks could be obtained with more “complex” systems, therefore isolating their advantages in a controlled manner is desirable. For the task of simple QA over knowledge graphs, the authors of Strong Baselines for Simple Question Answering over Knowledge Graphs with and without Neural Networks suggest to start with simple strong baselines of simple neural network or classical technique then move to more complexed system after adequately examine the baseline.

Since HHH: An Online Medical Chatbot System based on Knowledge Graph and Hierarchical Bi Directional Attention only considered the single-turn question-and-answer mechanism, an important future direction is to add user profiles into the system and provide a more precise and tailored medical assistant to each specific user.

#### Authors of Semantic Parsing for Single-Relation Question Answering propose replacing WikiAnswers data and ReVerb KB used in the experiments with a dedicated entity linking system. This will improve performance, reduce the number of candidate predicate/entity from the KB and tackle the problem of multiple-relation questions. We can replace the twin CNN network with a Bi-LSTM encoder+decoder or transformers to aim for higher similarity rate and therefore better F1 rate.

The entity linker used in Simple Question Answering by Attentive Convolutional Neural Network can also utilize the character-level neural network (LSTM or CNN) instead of word-level neural network to increase the possible match from the KG. The word-CNN in the fact selection can also use a transformer to take advantage of keeping the information of the work structure and order in the question.

#### Three main factors in the model proposed by Knowledge Graph Embedding Based Question Answering that increase the QA performance are to use embeddings - Glove in this research, BiLSTM, and a special distance function to measure the distance between the pattern/mention of the question and the relation/entity of the triples from the KG. Based on these, some future works may possibly be to change from Glove embedding representation to others such as Bert, to replace the BiLSTM with transformers to better have similarity and word paraphrases, or to tune the distance function.

## Comparison

Attention is All You Need focuses on effectively reducing the training time associated with a large corpus by using the attention mechanism and facilitating the parallelization of the computation required for training. The tasks used for evaluating the performance of the model are machine translation and constituency parsing. The inherent architecture involves both an encoder and a decoder.

SpanBERT: Improving Pre-training by Representing and Predicting Spans paper focuses on pre-training for more effectively representing the question and extracting the corresponding answer from a retrieved paragraph. As part of the fine-tuning phase, a Q & A task specific model should be used to predict the appropriate span-start and span-end locations for the response. Essentially it uses only the encoder stack of the transformer albeit with different parameters.

The TransferTransfo: A Transfer Learning Approach for Neural Network Based Conversational Agents paper essentially starts by pre-training a language model on the BooksCorpus dataset but effectively using only the decoder portion of the transformer essentially using Generative Pretrained Transformer-2. As part of the fine-tuning, the language model is modified to produce dialog (response) to user interaction.

The Personalizing Dialogue Agents: I have a dog, do you have pets too? Paper aims to improve the dialogue agents by providing them with a configurable persistent persona, encoded by multiple sentences of textual description. This profile can be stored in a memory-augmented neural network and then used to produce more personal, specific, consistent and engaging responses than a persona-free model, thus alleviating some of the common issues in open ended conversation models

The four papers [HHH: An Online Medical Chatbot System based on Knowledge Graph and Hierarchical Bi Directional Attention](https://arxiv.org/pdf/2002.03140.pdf) , [Semantic Parsing for Single-Relation Question Answering](https://www.aclweb.org/anthology/P14-2105/), [Simple Question Answering by Attentive Convolutional Neural Network](https://www.aclweb.org/anthology/C16-1164/), and [Knowledge Graph Embedding Based Question Answering](https://dl.acm.org/doi/10.1145/3289600.3290956)

aim at solving the same problem: how to find the best answer from the KG when the input question may have different paraphrases or ambiguous subjects. While all four models gain higher performance than their corresponding baseline systems, the [Semantic Parsing for Single-Relation Question Answering](https://www.aclweb.org/anthology/P14-2105/) and [Simple Question Answering by Attentive Convolutional Neural Network](https://www.aclweb.org/anthology/C16-1164/) papers take into account the case of out-of-vocab situation, while the other do not when they operate at the word level only. This is understandable because the KG Firebase and Quora Duplicate Questions have huge corpus sizes. With these corpus sizes, out-of-vocab seems diminished. Also, the [Knowledge Graph Embedding Based Question Answering](https://dl.acm.org/doi/10.1145/3289600.3290956) paper leverages word embedding representations and a special distance function while the others work on word similarity that are calculated through the models.

One difference between [Knowledge Graph Embedding Based Question Answering](https://dl.acm.org/doi/10.1145/3289600.3290956) and HHH: An Online Medical Chatbot System based on Knowledge Graph and Hierarchical Bi Directional Attention papers is how they handle questions that aren’t exist in the knowledge graph. Knowledge Graph Embedding Based Question Answering solves the problem by comparing the question’s entity and predicates embedding vector to those in KG and selecting the best candidate with distance metric called Joint Distance Metric. The HHH: An Online Medical Chatbot System based on Knowledge Graph and Hierarchical Bi Directional Attention paper also use similarity model but with Siamese framework and Manhattan distance to compute the sentence level semantic similarity

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