Research Statement

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1 Introduction

My research interests lie in the general area of Natural Language Processing or NLP (a field that studies how computers can interact with natural language: language spoken and written by humans). In particular, I am interested in the problem of Automatic Natural Language Understanding, i.e. creating models that can help in automatedly reading and reasoning about textual data. During a summer internship, I got an opportunity to work at IBM Research Labs and explore the problem of automatic *Question Answering* [1] which aims at training computer systems to read text documents and automatically finding answers to associated questions. The experience led me to realize that while mining patterns in large amounts of text data can lead to increased modeling capacity and efficient statistical inference, the existing practice of looking at surface representations of words, rather than modeling their meaning is inadequate for creating robust Natural Language Understanding systems. For instance, IBM's Watson system has successfully beaten humans in games like Jeopardy but it still struggling to answer sophisticated questions on a different domain such as medicine.

Some thought into the issues indicates that this paradigm of using *shallow representations* of text is inherently different from the processes involved in text comprehension by humans. While reading a story, humans are guided by their knowledge of semantic denotations of words, the composition of words to form sentences, patterns of discourse narratives in a paragraph, and so on. They can build temporal orderings of principal events in a story; infer the relationships between the characters in a story and explain how their actions affect (or might affect) each other etc. Finally, they can use semantic grounding and their world knowledge to build expectations about incoming words/events etc. and also to fill in gaps about what is not explicitly stated in a text. e.g., *Q: Will you go to a movie tonight? A: I have an exam tomorrow.*

Computer systems based on shallow representation, on the other hand, develop a very limited understanding of text while reading them which leads to problems like failure to answer sophisticated questions. Successful automatic Natural Language understanding thus requires better representations and models for language constructs and language phenomenon. Better representation could be achieved by designing context aware features that are based on real-world resources that take into consideration the semantics of words and relationships between them. Better models of language understanding could include ones which employ sophisticated techniques that model the development of the story in the text and also flow of information between various parts of the text. In the rest of this document I provide various examples of scenarios where we model world knowledge and the above mentioned flow of information to solve interesting problems.

2 Modeling inter-personal relationships in narratives

A major part of my current work focusses on one aspect of understanding natural language text: studying principal characters and the relationships between them in English language stories. Understanding these relationships is essential to understanding and explaining people's desires, goals, actions and expected behaviors. The problem presents subtleties that are not immediately obvious. For instance, consider 'The king of England asked the king of France to surrender, and he refused' and 'Tom asked his mother for another cookie, and she refused'. Despite surface and syntactic similarities, the relationships between characters is one of mutual hostility in one case, and asymmetric authority in the other. Solving this problem of inferring relationships would allow a computer to 'fill-in-the-blanks', and develop expectations about

S1: Tom falls in love with Becky Thatcher, a new girl in town, and persuades her to get "engaged" to him.
S2: Their romance collapses when she learns that Tom has been "engaged" before—to a girl named Amy Lawrence.
S3: Shortly after being shunned by Becky, Tom ...
S4: Back in school, Tom gets himself back in Becky's favor after he nobly accepts the blame for a book that she has ripped.
S5: Meanwhile, Tom goes on a picnic to McDougal's Cave with Becky and their classmates.

Figure 1: Sample sentences from a narrative depicting evolving relationship between characters: Tom and Becky. '. . . ' represent text omitted due to space constraints.

what might be a reasonable story. Filling-in-the-gaps is one of the fundamental abilities of humans which current computer systems lack. Identifying relationships would allow faithful modeling of character intentions and expected actions. For example, 'The king of England then imprisoned the king of France' is something that a reader might expect because they are adversaries, but 'Tom then imprisoned mother' would be very surprising.

Apart from applications related to general natural language understanding, modeling inter-personal relationships also finds application in many real-world domains such as social networks, discussion forums etc. Specifically, for my thesis, I model inter-personal relationships in natural language text with a focus on narratives. We demonstrate that such a task can benefit from using models that are capable of incorporating not just linguistic cues but also the contexts in which these cues appear.

We propose models to address the task of modeling the nature of relationships between any two given characters from the narrative. We attempt to jointly infer the relationships between all characters in the narrative and demonstrate how the task of identifying relationship between two characters can benefit by including information about their relationships with other characters in the movie [7] - a common world-knowledge which humans often inherently employ while reading stories. Such an approach enables incorporation of transitive relations like 'friend of a friend is a friend', 'common enemy of friends' etc.

We also formulate the relationship-modeling problem as a *structured prediction* task (a field of NLP that deals into modeling inputs/outputs that have an inherent structure eg. graphs, sequences, trees etc.) to model the evolving nature of human re-

lationships [4]. Most existing methods that model inter-personal relationships treat relationship as a unchanging variable, is not sufficient to explain *all* the events in the narrative. Real-world relationships are instead dynamic and change with the progress of the narrative. For example, consider the relationship between *Tom* and *Becky* depicted in Fig. 1 which shows an excerpt from the summary [1] of *The Adventures of Tom Sawyer*. For most of the narrative, the characters are participants in a romantic relationship, which explains most, but not all, of their mutual behavior. However, we can observe that their relationship was not stagnant but evolving, driving the characters' actions. In this particular case, the characters presumably start as lovers (sentence S1 in the figure), which is hinted at by (and explains) becoming engaged. The relationship sours when Tom reveals his previous love interest (S2 and S3). However, later in the narrative they reconcile (S4 and S5). To incorporate the evolving nature of relationships, we use structured models that make Markov assumptions and demonstrate the need to model history of relationships between characters while modeling their current relationship.

3 Understanding desire fulfillment

Understanding the structure in the text not only helps in modeling relationships between characters but other relevant tasks. For instance, consider the problem of reading a short narrative text to identify if a desire expressed in the text is fulfilled [3]. Expressions of desires and wishes have attracted psycholinguists [5] and linguists [6] alike. Analyzing desires adds a new dimension to more general tasks like opinion mining where the manufacturers and advertisers want to discover users' desires or needs from online reviews etc. Another use-case would be in resolving issues for community forum users. Identifying posts containing unresolved issues can help focus the efforts of the forum staff and interested members.

In this case also, we argue that it is insufficient to look for cues indicating desire fulfillment without understanding the text. Instead, it is important to understand the content of the narrative with respect

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[1] SparkNotes Editors. "SparkNote on The Adventures of Tom Sawyer." SparkNotes LLC. 2003. `http://www.sparknotes.com/lit/tomsawyer/`

to its central character - the person(s) who expressed the desire. We address this complexity by proposing a model which incorporates the narrative flow between individual sentences of the text, while assessing if the events (and emotional states) mentioned in this flow contribute to (or provide indication of) fulfilling the desire.

4 Identifying thread resolution in discussion forums

Apart from narratives, there are several other sources of natural language text that demand deeper understanding, eg. discussion forums. Most existing methods for solving problems related to discussion forums base their approach on either meta-data or a shallow 'bag-of-words' style representation of text. Instead, there is a need to understand the content of individual posts and their relationship to each other. We analyze contents of online educational discussion forums to automatically suggest threads to the instructors that require their intervention [2]. By suggesting avenues for instructor-student interaction, we alleviate the need for the instructor to manually go over all threads of the forum and also help the students who have no other way of directly interacting with the instructor. In this problem we argue that it is important to understand the content of the thread post-by-post and model the flow of information between the posts to solve this problem. We propose to incorporate thread structure into our approach by using latent variables that abstractly represent contents of individual posts and model the flow of information in the thread. A structured approach that incorporates the flow of information in the thread performs better at the prediction task than an unstructured approach that simply extracts features from all the posts of the thread collectively.

5 Future Work

In future I would like to do a more in-depth analysis of novels, devising methods to pick-up subtle cues about relationships based on varying literary styles of authors. This direction could be used to answer questions like 'What kind of novels have happy endings?', 'Are there general narrative templates of relationship evolution between the protagonist and his/her lover?'

etc. Exploiting the dynamic nature of relationships can also find application in social media domain. For instance, social networking sites could use this phenomenon for customizing news feeds. Human relationships are often governed by geographical proximity, common interests etc. A change in these factors could lead to a change in nature/strength of relationship and hence change in interest in 'news' related to the other person.

Apart from modeling relationships, I would like to explore other challenging problems related to natural language understanding which include solving pedagogical exercises such as reading-comprehension questions, simple math word-problems etc. These problems also require understanding text to answer questions related to the text. Even though the answer to the questions are present in the text, these problems are currently, not solvable to a satisfactory level by computers.

Based in these techniques, it would be possible to design a system that can read and comprehend large documents with a goal not limited to answering questions or modeling relationships etc., but to a more human-like behavior of expanding its knowledge-base. Such a system would have a knowledge and understanding of the world like human albeit at a much larger scale and could be used for several downstream NLP tasks involving text comprehension.

References

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