Natural Language Processing: An Overview

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Talk Outline

• Introduction to Natural Language Processing
• State-of-the-Art Technologies of Natural Language Processing
• Future Trends of Natural Language Processing
Ultimate Goal: Natural Language Understanding

Natural Language Dialogue  Text Comprehension
Natural Language Understanding

• Two definitions:
  – Representation-based: if system creates proper internal representation, then we say it “understands” language
  – Behavior-based: if system properly follows instruction in natural language, then we say it “understands” language, e.g., “bring me a cup of tea”

• We take the latter definition
Five Characteristics of Human Language

• Incompletely Regular (Both Regular and Idiosyncratic)
• Compositional (or Recursive)
• Metaphorical
• Associated with Knowledge
• Interactive
Natural Language Understanding by Computer Is Extremely Difficult

• It is still not clear whether it is possible to realize human language ability on computer

• On modern computer
  – The incomplete regularity and compositionality characteristics imply complex combinatorial computation
  – The metaphor, knowledge, and interaction characteristics imply exhaustive computation

• Big question: can we invent new computer closer to human brain?
Reason of Challenge

• A computer system must be constructed based on math

• Open question: whether it is possible to process natural language as humans, using math models

• Natural language processing is believed to be AI complete
Simplified Problem Formulation - Eg., Question Answering

- Decision
- Retrieval
- Inference
- Understanding
- Analysis

- Generation
- Retrieval
- Analysis

Question answering, including search, can be practically performed, because it is simplified.
Data-driven Approach Works

• Hybrid is most realistic and effective for natural language processing, and AI
  – machine learning based
  – human-knowledge incorporated
  – human brain inspired

• Big data and deep learning provides new opportunity
Advancement in AI, including NLP can be made through the closed loop
Fundamental Problems of Statistical Natural Language Processing

• Classification: assigning a label to a string
  \[ S \rightarrow C \]

• Matching: matching two strings
  \[ s, t \rightarrow R^+ \]

• Translation: transforming one string to another
  \[ s \rightarrow t \]

• Structured prediction: mapping string to structure
  \[ s \rightarrow s' \]

• Markov decision process: deciding next state given previous state and action
Fundamental Problems of Statistical Natural Language Processing

• Classification
  – Text classification
  – Sentiment analysis

• Matching
  – Search
  – Question answering
  – Dialogue (single turn)

• Translation
  – Machine translation
  – Speech recognition
  – Hand writing recognition
  – Dialogue (single turn)

• Structured Prediction
  – Named entity extraction
  – Part of speech tagging
  – Sentence parsing
  – Semantic parsing

• Markov Decision Process
  – Dialogue (multi turn, task dependent)
Lower Bound of User Need vs Upper Bound of Technology

Lower Bound of User Need

Pushing Upper Bound of Technology

Upper Bound of Technology
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Applications

- Question Answering
- Image Retrieval
- Single Turn Dialogue
- Machine Translation
Question Answering
- DeepMatch CNN
Retrieval based Question Answering System

1. **Online**
   - **Question**
   - **Retrieval**
   - **Matching**
   - **Ranking**
   - **Best Answer**

2. **Offline**
   - **Index of Questions and Answers**
   - **Matching Models**
   - **Ranking Model**

- **Retrieved Questions and Answers**
- **Matched Answers**
- ** Ranked Answers**
Deep Match Model CNN

- Represent and match two sentences simultaneously
- Two dimensional model
- State of art model for matching in question answering
Image Retrieval
- Multimodal CNN
Demo
Multimodal CNN

- One Convolutional Neural Network represents image
- One Convolutional Neural Network represents text
- Multi Layer Perceptron conducts matching
Natural Language Dialogue
- Neural Responding Machine
Demo
Neural Responding Machine

太羡慕你了祝旅行愉快

• Using both local and global attention mechanisms
Neural Machine Translation
- Google Neural Machine Translation
Google Neural Machine Translation

- Sequence-to-Sequence Learning Model
- With 8 layer encoder, 8 layer decoder
- Residual connections and attention connections from bottom of decoder to top of encoder
- Model partition and data partition
- Use sub-word units for both input and output to deal with rare words
- Use length normalization and coverage penalty
Architecture of Google Neural Machine Translation
Talk Outline

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<table>
<thead>
<tr>
<th>Task</th>
<th>Setting</th>
<th>Problem Formulation</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic Speech Recognition</td>
<td>Ideal Environment</td>
<td>Translation</td>
<td>95%</td>
</tr>
<tr>
<td>Dialogue</td>
<td>Single Turn</td>
<td>Classification or Structured Prediction</td>
<td>80%-90%</td>
</tr>
<tr>
<td>Dialogue</td>
<td>Multi Turn</td>
<td>Markov Decision Process</td>
<td>50%-70%</td>
</tr>
<tr>
<td>Question Answering</td>
<td>Single Turn</td>
<td>Matching</td>
<td>70%-80%</td>
</tr>
<tr>
<td>Machine Translation</td>
<td>Written Language Translation</td>
<td>Translation (derived from BLEU score)</td>
<td>70%-80%</td>
</tr>
</tbody>
</table>
Trend One: Speech Recognition and Translation Are Taking off

• Automatic Speech Recognition is being widely used in language input
• Written Language Translation will be more widely used in practice
• Spoken Language Translation will be gradually utilized and improved
• There are still issues to be solved, e.g., long tail challenge
Trend Two: Single Turn Dialogue and Single Turn Question Answering Will Take-off

• Task-dependent single turn dialogue will be gradually used
• Single turn question answering will be gradually used
• They can be extended to multi turn with heuristics
• Open question: is generation-based single turn dialogue practically useful?
Trend Three: Multi-Turn Dialogue Needs More Research

- Must be task-dependent
- Reinforcement Learning can be key technology
- Data needs to be collected first, and then the AI loop can be run
- Simple (not complex) task-dependent multi-turn dialogue will be realized
- Chatbot is very difficult, performance is not high with only single turn technologies used
Summary

• Natural Language Understanding is difficult
• Five fundamental problems in natural language processing
• AI loop is important
• Deep learning achieves state of the art performance, particularly for machine translation
• Speech recognition, translation, single turn dialogue, single turn question answering technologies will be continuously improved and gradually used in practice
References

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Thank you!