Learning to Process Natural Language in Big Data Environment

Hang Li
Noah’s Ark Lab
Huawei Technologies
Part 3: Deep Learning for Natural Language Processing
At Noah’s Ark Lab
DL for NLP @Noah Lab

Researchers

Zhengdong Lu
Lifeng Shang
Lin Ma
Zhaopeng Tu

Interns

Baotian Hu
Fandong Meng
Mingxuan Wang
Han Zhao
Research on Deep Learning for Natural Language Processing

• Goal
  – Develop advanced deep learning technologies for natural language processing

• Tasks We Are Working on
  – Semantic Matching
  – Machine Translation
  – Image Retrieval
  – Natural Language Dialogue
Semantic Matching
It is really hot
[Intent: please open the window]

Mary is loved by John
[act: love;agt: John; obj: Mary]

I ate icecream [with a spoon]
I ate icecream [with chocolate]

[南京市] [长江大桥]
[南京] [市长] [江大桥]
Avoid ‘Understanding’ but Conduct Matching

- Machine Translation: A language = source language, B language = target language
- Question Answering: A language = question, B language = answer
- Information Retrieval: A language = query, B language = document
Semantic Matching Plays Key Role

• Applications
  – Search
  – Question Answering
  – Paraphrasing
  – Dialogue (Single Turn)
  – Image Annotation
  – Machine Translation

• Matching vs translation
  • Matching
    \[ s, t \rightarrow R^+ \]
  • Translation
    \[ s \rightarrow t \]
Our Proposed Deep Match Models

• Deep Match Topic (Lu & Li, NIPS 2013)
• Deep Match CNN (Hu et al., NIPS 2014)
• Deep Match Tree (Wang et al. IJCAI 2015)
Deep Match CNN - Architecture I

• First represent two sentences as vectors, and then match the vectors
Deep Match CNN - Architecture II

- Represent and match two sentences simultaneously
- Two dimensional model
Deep Match Tree

• Based on dependency parsing
• Deep neural network for matching, with first layer representing mined matching patterns
Dependency Tree Pattern Mining

Direct Product of Trees

Mined Patterns

<table>
<thead>
<tr>
<th>Patterns with abstraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>hope→win→x ⊖ support→x</td>
</tr>
<tr>
<td>how about→x ⊖ like→x</td>
</tr>
<tr>
<td>gift→x ⊖ happy→x</td>
</tr>
<tr>
<td>recommend→x ⊖ x→nice</td>
</tr>
<tr>
<td>pretty good→x ⊖ fine→also→x'</td>
</tr>
</tbody>
</table>
Conclusions from Experiments

- Deep Match CNN and Deep Match Tree are complimentary
- Both can be used as features of learning to rank model
- When there is enough data, Deep Match CNN Arc II works better than Deep Match CNN Arc I
Image Retrieval
Image Retrieval System

Find the picture that I had dinner with my friends at an Italian restaurant in Hong Kong

• Scenario
  – Image search on smartphone
  – Key: matching text to images

• Technology
  – Deep model for matching text and image
Our Proposed Deep Match Models

- Text Image Match Model (Ma et al. ICCV 2015)
Deep Match Model for Image and Text - CNN Based

- Represent text and image as vectors and then match the two vectors
- Word-level matching, phrase-level matching, sentence-level Matching
Word-level Matching and Phrase-level Matching

Word Level Matching

Phrase Level Matching
Sentence-level Matching

Sentence Level Matching
Deep Match Model for Image Retrieval

- Top 10 Recall > 60%
- Outperforms all existing methods in image retrieval
Conclusions from Experiments

• Sentence level matching and phrase level matching work best
• Better to combine models at all levels
• Our models (CNN) work better than state of the art models (RNN)
Machine Translation
Motivation

• Improve performance of SMT (statistical machine translation) system
• Proposed using CNN model for learning sentence representation (Hu et al., 2014)
• Question: can we learn powerful features for SMT using CNN?
• Answer:
  – Joint language model using CNN
  – Language model using CNN
Our Proposed Models

• CNN-based Language Model (Wang et al., ACL-IJCNLP2015)
• CNN-based Joint Language Model (Meng et al., ACL-IJCNLP 2015)
• CNN-based Translation Selection (Hu et al., ACL-IJCNLP 2015, short)
Neural Network Joint Model
(Devlin et al., 2014)

• Language model of target sentence conditioned on source sentence

\[
P(T \mid S) = \prod _ {i=1} ^ {\left|T\right|} \left( P(t_i \mid t_{i-1}, \ldots, t_{i-n+1}, s_{(a_i-m-1)/2}, \ldots, s_{a_i}, \ldots, s_{(a_i-m-1)/2}) \right)
\]

- $s_{a_i}$ affiliated (aligned) word of $t_i$
- $(n + m)$-gram language model

• Use Neural Network Language Model to learn the model

Devlin et al., Fast and robust neural network joint models for statistical machine translation.
ACL 2014
CNN based Joint Language Model

- Capture local structures of source sentence using CNN
- tagCNN uses aligned word
- inCNN uses `attention signal’
CNN based Language Model

• Capture local structures of sentence using CNN
• Recursively connect $\alpha$CNN and $\beta$CNN
Conclusions from Experiments

• Overall 2 point BLEU score improvement
• tagCNN and inCNN work better than BBN model (Devlin et al., 2014)
• tagCNN and inCNN are complementary
• CNN based language model works better than RNN based language model
Natural Language Dialogue
Natural Language Dialogue

• Vast amount of conversation data is available
• Powerful technologies like deep learning developed
• Single turn vs multi-turn dialogue
• Two approaches
  – Retrieval based
  – Generation based

NTCIR: Short Text Conversation Contest
5.5 million message response pairs
Our Proposed Models

• Retrieval-based
  – Deep Match CNN (Hu et al., NIPS 2014)
  – Deep Match Tree (Wang et al. IJCAI 2015)

• Generation-based
  – RNN based Neural Responding Machine (Shang et al., ACL-IJCNLP 2015)
Natural Language Dialogue System
- Retrieval based Approach

message

retrieval

retrieved messages and responses

matching

matched responses

ranking

ranked responses

best response

index of messages and responses

matching models

ranking model
Retrieval based Dialogue System (Ji et al., 2014)

• Matching Models (Features)
  – Deep Match CNN
  – Deep Match Tree
  – Vector Space Model
  – Translation Model

• Ranking Model
  – Ranking SVM

Ji et al., An Information Retrieval Approach to Short Text Conversation, arXiv, 2014
Retrieval based Approach:
Accuracy = 70%+

上海今天好熱，堪比新加坡。
It is very hot in Shanghai today, just like Singapore.

上海今天热的不一般。
It is unusually hot.

想去武当山 有想同游的么？
I want to go to Mountain Wudang, is there anybody going together with me?

我想跟帅哥同游~哈哈
Haha, I want to go with you, handsome boy

Using 5 million Weibo Data
RNN based Neural Machine Translation

• Global translation model (Cho et al., 2014)

[Diagram of Global Translation Model]

• Local translation model (Bahdanau et al., *arXiv* 2014)

[Diagram of Local Translation Model]


Bahdanau, et al. Neural machine translation by jointly learning to align and translate.
Natural Language Dialogue System - Generation based Approach

- Encoding messages to intermediate representations
- Decoding intermediate representations to responses
- Recurrent Neural Network (RNN)
Generation based Approach
Accuracy = 76%

占中终于结束了。  Occupy Central is finally over.

下一个是陆家嘴吧？  Will Lujiazui (finance district in Shanghai) be the next?

我想买三星手机。  I want to buy a Samsung phone

还是支持一下国产的吧。  Let us support our national brands

vs. Accuracy of translation approach = 26%
Accuracy of retrieval based approach = 69%
Conclusions from Experiments

• Both retrieval based approach and generation based approach work well
• > 70% accuracy
• Generation based approach is more robust
• Retrieval based approach is safer
• Evaluation is big issue
Summary

• Noah’ Ark Lab is working on deep learning for natural language processing

• Significant progresses have been made in
  – Semantic Matching
  – Machine Translation
  – Natural Language Dialogue
References

References


• Lin Ma, Zhengodng Lu, Lifeng Shang, Hang Li . Multimodal Convolutional Neural Networks for Matching Image and Sentence, ICCV’15, 2015.
Thank you!

hangli.hl@huawei.com