Disambiguating Natural Language via Aligning Meaningful Descriptions

Final Dissertation Defense
Yida Xin
27 June 2022
Acknowledgement

This work is made possible by Prof. Peter Chin, Prof. Steve Homer, Prof. Derry Wijaya, Dr. Henry Lieberman, Pedro Colon-Hernandez, my BULISP colleagues, and my MIT Genesis colleagues.
Ambiguities are the core difficulty for computers …

… because computers lack commonsense

Ambiguities accumulate from sentences to discourses

Ambiguities should be resolved in transparent ways
Commonsense Disambiguation Hypothesis

- Disambiguation is the application of commonsense inference to language understanding.

- Disambiguation at all levels would solve most, if not all, of language understanding.
Research Strategy

- Simple disambiguation for sentences
- More sophisticated reasoning for sentences
- Simple disambiguation for discourses
- More sophisticated reasoning for discourses
Early On I Discovered That…

- Many sentence-level ambiguities are context-independent

- Most discourse-level ambiguities are context-dependent
• PatchComm: Sentences, Context-independent Disambiguation
  ▪ Simple disambiguation, using ConceptNet
  ▪ Sophisticated inferences, using RetroGAN-DRD

• ProGeneXP: Implicit contexts -> Transparent descriptions

• DialComm: Discourses, Context-dependent Disambiguation
  ▪ Simple disambiguation, via alignment
  ▪ Sophisticated inferences, using LM-GAN
PatchComm: Sentences, Context-independent Disambiguation
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ProGeneXP: Implicit contexts → Transparent descriptions

DialComm: Discourses, Context-dependent Disambiguation
- Simple disambiguation, via alignment
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PatchComm: Context Indep Disambiguation

Diagram:
- Commonsense Module
  - Description Alignment
  - Commonsense Guidance
- Syntactic Parsing Module
  - Sentence
  - Syntactic parse tree
ConceptNet: Commonsense Knowledge Base

- **en** cake → *IsA* → **en** dessert
- **en** a person → *Desires* → **en** eat
- **en** A person → *CapableOf* → **en** Eat
- Prepositional Phrase Attachment Ambiguity
- Pronoun Coreference Ambiguity
PatchComm: Prepositional Phrase Attachment

Query ConceptNet to Align Descriptions

The girl [SUBJ] saved the bird [OBJ] with one wing [PP]

girl save bird wing

en wing — PartOf → en bird
PatchComm Makes More Common Sense
Disambiguate Multiple Prepositional Phrases

**spaCy**

The DET
girl NOUN
saved VERB
the DET
bird NOUN
with ADP
nummod
prep
the DET
tree NOUN

**PatchComm**

The DET
girl NOUN
saved VERB
the DET
bird NOUN
with ADP
nummod
prep
the DET
tree NOUN
Testing PatchComm with ConceptNet

Prepositional Phrase Attachment

- Self-created dataset of 100 prepositional phrase sentences.
  - “The journalists reported the profits in the newspapers”
  - “The journalists reported the profits in the commodities”

<table>
<thead>
<tr>
<th></th>
<th>spaCy</th>
<th>spaCy + PatchComm w/ ConceptNet</th>
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</thead>
<tbody>
<tr>
<td>Self-created</td>
<td>57.0%</td>
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</table>
PatchComm: Pronoun Coreference

Query ConceptNet to Align Descriptions

The knife [ENT₁]
cuts through
the butter [ENT₂]
because it [PRON]
is soft [DESC]

knife
butter
soft

en butter — HasProperty —> en soft
PatchComm Makes More Common Sense

PatchComm

The DET knife NOUN cuts VERB through ADP the DET butter NOUN because SCONJ it PRON is AUX soft ADJ

NeuralCoref

The knife NOMINAL cuts through the butter NOMINAL because it PRONOMINAL is soft.

spaCy

The DET knife NOUN cuts VERB through ADP the DET butter NOUN because SCONJ it PRON is AUX soft ADJ
Testing PatchComm with ConceptNet

Pronoun Coreference

- Winograd Schema Challenge (WSC273) dataset.
  - “The trophy doesn't fit in the brown suitcase because it's too big.”
  - “The trophy doesn't fit in the brown suitcase because it's too small.”

<table>
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<th>NeuralCoref</th>
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• PatchComm: Sentences, Context-independent Disambiguation
  ▪ Simple disambiguation, using ConceptNet
  ▪ Sophisticated inferences, using RetroGAN-DRD

• ProGeneXP: Implicit contexts -> Transparent descriptions

• DialComm: Discourses, Context-dependent Disambiguation
  ▪ Simple disambiguation, via alignment
  ▪ Sophisticated inferences, using LM-GAN
RetroGAN-DRD: Improving the Inferences

(Pedro Colon-Hernandez et al.)
Architecture of RetroGAN

(Collaboration with Pedro Colon-Hernandez et al.)
Retrofitting Distributional Word Embeddings with Knowledge Embeddings
Post-Specialization for Out-of-Knowledge

Out-of-Knowledge

In-Knowledge

Post Specialization

Retrofitting

Post-Specialized Out-of-Knowledge

Retrofitted In-Knowledge
RetroGAN: (1) Specialization

\[ S(B_S) = \sum_{(x_l, x_r) \in B_S} \left[ \tau (\delta_{syn} + x_l t_l - x_l x_r) + \tau (\delta_{syn} + x_r t_r - x_l x_r) \right] \]

\[ A(B_A) = \sum_{(x_l, x_r) \in B_A} \left[ \tau (\delta_{ant} + x_l x_r - x_l t_l) + \tau (\delta_{ant} + x_l x_r - x_r t_r) \right] \]
RetroGAN: (2) Post-Spec with CycleGAN

\[ L(G, F, D_X, D_Y) = L_{GAN}(G, D_Y, X, Y) + L_{GAN}(F, D_X, X, Y) + \lambda L_{CYC}(G, F) + \gamma L_{ID}(G, F, X, Y) + L_{MM}(G, F, X, Y) + \zeta L_{CYC}(G, F, D_{cX}, D_{cY}, X, Y) \]
Testing RetroGAN for Out-of-Knowledge

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<td>SL</td>
<td>SV</td>
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<td>RetroGAN</td>
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<td><strong>0.738</strong></td>
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<td>0.490</td>
<td>0.688</td>
<td>0.597</td>
<td>0.480</td>
<td>0.690</td>
<td>0.601</td>
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<td>RetroGAN</td>
<td>0.755</td>
<td>0.716</td>
<td><strong>0.511</strong></td>
<td>0.763</td>
<td>0.721</td>
<td><strong>0.507</strong></td>
<td>0.762</td>
<td>0.715</td>
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Commonsense Inference via Deep Relationship Discovery
Commonsense Inference via Deep Relationship Discovery

Inferred

Boston University Department of Computer Science
Testing PatchComm with RetroGAN-DRD

- Prepositional Phrase Attachment
  - “The journalists reported the profits in the newspapers/commodities”
- Pronoun Coreference
  - “The trophy doesn't fit in the brown suitcase because it's too big/small.”

<table>
<thead>
<tr>
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<th>Baseline</th>
<th>Baseline + PatchComm w/ConceptNet</th>
<th>Baseline + PatchComm w/ RetroGAN-DRD</th>
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<td>Self-created</td>
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<td>WSC273</td>
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PatchComm: Context Independent Disambiguation
- Simple disambiguation for sentences, using ConceptNet
- Sophisticated reasoning for sentences, using RetroGAN-DRD

ProGeneXP: Implicit contexts -> Transparent descriptions

DialComm: Context Dependent Disambiguation
- Simple disambiguation for discourses, via alignment
- Sophisticated reasoning for discourses, using LM-GAN
ProGeneXP: Generating Descriptions to Make Implicit Contexts Transparent

Stage 1: Recurrent Fine-tuning

Stage 2: Task Specialization

Boston University Department of Computer Science
# Recurrent Fine-tuner Targets Transparency

| Sentence: The infection spread throughout the building because [it] was airborne. |
|---|---|
| **Human** | Airborne viruses can spread quickly in ventilated in-door areas. |
| **Plain model** | The infection spread throughout the building because [it] was airborne. |
| **RF model** | Airborne viruses can spread quickly in a building. |

| Sentence: The infection spread throughout the building because [it] was ventilated. |
|---|---|
| **Human** | Airborne viruses can spread quickly in ventilated in-door areas. |
| **Plain model** | Infection spread because the building was not ventilated. |
| **RF model** | Ventilation can spread infection throughout a building. |

| Sentence: The smoke spread through the building because [it] was caught on fire. |
|---|---|
| **Human** | — |
| **Plain model** | Smoke spread through the building because [it] was on fire. |
| **RF model** | Smoke is created when a building is on fire |

| Sentence: The smoke spread through the building because [it] came from the fire. |
|---|---|
| **Human** | — |
| **Plain model** | Smoke spread through the building because [it] came from the fire. |
| **RF model** | Smoke from a fire can spread quickly in a building. |
Preliminary Testing of ProGeneXP on Coreference

- Dataset: WinoGrande (WSC273-like sentences)

<table>
<thead>
<tr>
<th>Test</th>
<th>Train</th>
<th>BERT (cased)</th>
<th>BERT (uncased)</th>
<th>RoBERTa</th>
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<tr>
<td></td>
<td>–</td>
<td>with desc</td>
<td>–</td>
<td>with desc</td>
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<tr>
<td>WG-valid</td>
<td>0.867</td>
<td>0.859</td>
<td>0.863</td>
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<tr>
<td>WG-valid with desc</td>
<td>0.840</td>
<td><strong>0.867</strong></td>
<td>0.828</td>
<td><strong>0.858</strong></td>
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</table>

- Ongoing Work:
  - Using ProGeneXP to find better descriptions for PatchComm
PatchComm: Context Independent Disambiguation
- Simple disambiguation for sentences, using ConceptNet
- Sophisticated reasoning for sentences, using RetroGAN-DRD

ProGeneXP: Implicit contexts -> Transparent descriptions

DialComm: Context Dependent Disambiguation
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DialComm: Context Dep Disambiguation
Aligning Descriptions into Frame

S1: Robbie and Susie are going to Marvin’s birthday party.
S2: One of them wants to buy a kite.
S3: “But he already has one,” he says, “he will make you take it back.”

<table>
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<tr>
<th>Hosts</th>
<th>Marvin</th>
<th>Gender</th>
<th>Male</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Gender</td>
<td>Male</td>
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<tr>
<td></td>
<td></td>
<td>Dialogs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Susie</td>
<td>Gender</td>
<td>Female</td>
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<tr>
<td></td>
<td></td>
<td>Dialogs</td>
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<tr>
<td>Attenees</td>
<td>Robbie</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gifts</td>
<td>Kite</td>
<td>From: Susie</td>
<td>To: Marvin</td>
</tr>
</tbody>
</table>

en gifts — AtLocation —> en a party
DialComm for Interactive End-User Programming in Natural Language

Boston University Department of Computer Science
I found a bar with a bartender who was making fancy drinks. If a drink was in the menu, the bartender would make it. One customer was rude, so the bartender threw away their drink.

class Bar:
    def __init__(self):
        self.bartender = Bartender()
        self.properties = []

class Bartender:
    def __init__(self):
        self.properties = []
    def make(self, drink):
        if drink in menu:
            pass
    def throw(self, drink):
        pass

class Drink:
    def __init__(self):
        self.properties = ['fancy']

class Menu:
    def __init__(self):
        self.properties = []

class Customer:
    def __init__(self):
        self.properties = ['rude']
PatchComm: Context Independent Disambiguation
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LM-GAN: Context-Dependent Inference via Hinting + Joint Inference + Adversarial Training

(LCollaboration with Pedro and friends.)

Lia was starting high school at a new school. She was afraid. She thought nobody would like her. But all the students were kind to her. Lia made many friends on her first day!

Specific:
Lia goes to new school
>Causes> Lia is afraid.

General:
PersonX goes to new school
>Causes> PersonX is afraid.

Adversarial Loss
Real or Not? Factual or Not?
Confounder Loss
She was afraid.
## Striking a balance between Recall and Precision

<table>
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<tr>
<th>Model</th>
<th>ROUGE-1</th>
<th>ROUGE-2</th>
<th>ROUGE-L</th>
<th>ROUGE-L-SUM</th>
<th>BLEU</th>
<th>METEOR</th>
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<tbody>
<tr>
<td>+ ADV + CONF</td>
<td>43.656</td>
<td>10.544</td>
<td>40.380</td>
<td>40.379</td>
<td>31.335</td>
<td>61.683</td>
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<tr>
<td>+ ADV – CONF</td>
<td>43.747</td>
<td>10.559</td>
<td>40.530</td>
<td>40.531</td>
<td>31.279</td>
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<tr>
<td>– ADV + CONF</td>
<td>43.715</td>
<td>10.680</td>
<td>40.292</td>
<td>40.292</td>
<td>31.470</td>
<td>61.776</td>
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Honorable Mention...

Transformer

BERT
Contributions

- Tested PatchComm on disambiguating sentences
- Showcased ProGeneXP on bringing context into sentences
- Implemented DialComm to disambiguate discourses and enabled end-user programming in natural language
- Incorporated commonsense into language understanding
- Set the stage for further advances in NLU and Commonsense