# Word Games

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# Dialogue

- Communication is rarely unambiguous
  - Ambiguity resolution through dialogue
  - Clarification questions
- Interactive, symmetric reference games
  - Isolates ambiguity resolution
  - Both give and request information

# Games

Friends of agent A:

| Name | School | Major | Company |
|------|--------|-------|---------|
| Jessica | Columbia | Computer Science | Google |
| Josh | Columbia | Linguistics | Google |
| ... | ... | ... | ... |

A: Hi! Most of my friends work for Google
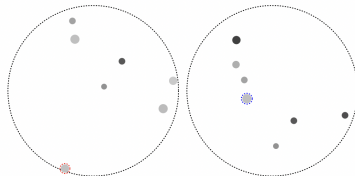B: do you have anyone who went to columbia?
A: *Hello?*
A: I have Jessica a friend of mine
A: and Josh, both went to columbia
B: *or anyone working at apple?*
B: SELECT (Jessica, Columbia, Computer Science, Google)
A: SELECT (Jessica, Columbia, Computer Science, Google)



Human A's view    Human B's view

Human B: three light grey dots in a diagonal line
Human A: i dont have that but i have a black
         dot neer the top to the right, the only
         black dot in the circle
Human B: i have two black dots. find something else
Human A: ok i have a light grey dot by itself
         at the bottom to the left. right on the line
Human B: how big is it
Human A: its one of the bigger ones
Human B: okay just pick it then
Human A: ok
Human B: SELECT blue
Human A: SELECT red

Mutual Friends and OneCommon

# Issue: Poor neural reasoning

From Mutual Friends: Neural + Human

- ► A: Know anyone who likes chess?
- ► B: None of my friends like chess.
- ► (conversation continues)
- ► A: Crocheting?
- ► B: None like crocheting.
- ► A: Chess?
- ► B: None like chess either, haha.

# Issue: Poor neural reasoning



Agent 0: human || 1: human

|  | 0 | 1 |
|---|---|---|
| 0 | 1 | I see a large grey dot with a smaller black dot right below it |
| 1 | 0 | is the smaller black dot to the right and below |
| 2 | 1 | No, it is slightly to the left and below |
| 3 | 0 | Might not be the same one. Do you have a lot of dots in a fairly vertical conformation |
| 4 | 1 | I have three dots in a kinda vertical line with different shade of gray but close in size |
| 5 | 0 | Is the middle dot curved to the left or right a little bit? |
| 6 | 1 | the middle dot is slighty to the left of the other two and is also a little bit darker than the rest |
| 7 | 0 | Yes pick that middle dot |

# Issue: Poor neural reasoning
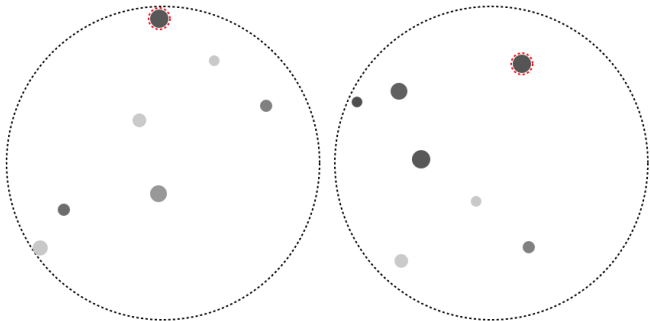


Agent 0: pragmatic_confidence || 1: human

|   | 0 | 1 |
|---|---|---|
| 0 | 0 | i have one large black dot by itself . do you have it ? |
| 1 | 1 | Yes, I do have that. |
| 2 | 0 | let 's pick that one |
| 3 | 1 | ok |
| 4 | 0 | ok |

# Issue: Scaling rule-based

| System | $C$ | $C_T$ | $C_S$ |
|---|---|---|---|
| Human | .89 | .07 | .36 |
| Rule | **.88** | **.06** | **.29** |
| StanoNet | .76 | .04 | .23 |
| DynoNet | .87 | .05 | .27 |

- ▶ Rule-based text generation and understanding is viable for Mutual Friends
- ▶ Continuous and spatial nature of OneCommon makes writing rules difficult

# Current approaches: Two extremes

- Neural encoder-decoder
  - Encode past interactions with a neural net
  - Generate what to say with a neural net
  - Brittle strategy, less brittle language
- Rule-based
  - Encode past interactions in a table
  - Use rules for what to say next
  - Nonparametric lookup of utterances
  - Brittle language, less brittle strategy
- Meet in middle with interpretable planning + neural language

# A dialogue turn

- ▶ Engaging in dialogue requires
  - ▶ Inference: What do I know? How do I represent it?
  - ▶ Planning: What should I do and say?
- ▶ Formulate as model-based optimization
  - ▶ Plan what to say through a simple model of our partner
  - ▶ Model of partner conditions on past information

# Problem setup

- ▶ Goal: Mutually select the same item as partner
  - ▶ Row in knowledge base, dot
  - ▶ Coordinate through dialogue
- ▶ Given history $h$, we need to chose an action $a$ by optimizing value

$$\max_a V(h, a)$$

- ▶ Value $V =$ information gain
  - ▶ Gain in item selection probability
- ▶ Represent $h, a$ using attributes
  - ▶ Columns of knowledge base, spatial configuration of dots

# Value: Information Gain

- A good action should move us closer to game success
- Game success depends on our knowledge of our partner's context
- Requires
  - Belief distribution over selection item given history $p(i \mid h)$
  - Partner response model $p(o \mid h, a, i)$
- Represent a turn as
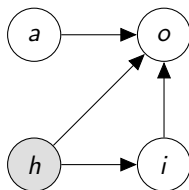


- Language and planning coupled

# Decoupling language and planning

- ▶ Compress actions *a* and observations *o* into language and abstract representations $\tilde{a}, \tilde{o}$
  - ▶ Language is high dimensional, redundant, and inefficient for planning
- ▶ Represent a turn as
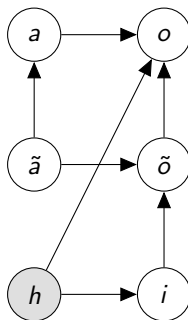


- ▶ Abstract observation $\tilde{o} \perp\!\!\!\perp h \mid \tilde{a}, i$

# State and belief: Representation

- History: whether attributes have been confirmed $h \in \{0,1\}^N$
- Items: $i \in [M], N >> M$
- $p(i \mid h) = \frac{\exp(\sum_n \psi(h_n, i))}{\sum_{i'} \exp(\sum_n \psi(h_n, i'))}$
- $\psi(h_n, i) = w_n 1(h_n(i))$
- Logistic regression with attributes as features
  - Attribute-based LR + Info gain = rules
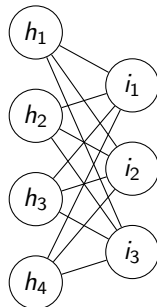
# Attributes

- Mutual Friends
    - Combinations of columns of knowledge base
    - Name, major, company
- OneCommon
    - Which dots are mentioned
    - Need to learn lower-level attributes
- Numerical reasoning

# Experiments

- ▶ Mutual Friends
  - ▶ Augment rule-based (prior work) to optimize info gain
  - ▶ After OneCommon: Add neural on top
- ▶ OneCommon
  - ▶ Use attributes = raw mention configurations
    - ▶ Everything already in system, except for belief / info gain
  - ▶ Learn latent refinement on top of mention configurations
    - ▶ How to deal with redundancy? (i.e. correlation between features)

# End

# Concerns

- Would a large LM solve all of this?
    - Fine tune on small onecommon dataset, are there still repeats?
    - Unlikely to solve strategy / over optimistism

# End

# Value: Information Gain

- drop slide
- Picture would be much better here...
- Value = expected information gain

$$IG(h, a) = H(i \mid h) - \mathbb{E}_{p(o \mid h,a)} \left[ H(i \mid h, a, o) \right]$$

$$\mathbb{E}_{p(o \mid h,a)} \left[ H(i \mid h, a) \right] = \sum_o \sum_{i'} p(o \mid h, a, i) p(i \mid h) H(i \mid h, a, o)$$

- Equivalent to minimizing expected uncertainty after receiving a response
- Cite Yu et al, White et al

# Issues with information gain

- ▶ Too much burden on the obs model $p(o \mid h, a, i)$
  - ▶ When $o$ is natural language, conditioning on $h$ is important
  - ▶ If we had a great obs model, would we have really have issues with solving these simple dialogue games?
- ▶ Proposal: Set up models for success by separating language from strategy
  - ▶ Rule-based representations good for strategy
  - ▶ Neural models good for language
- ▶ Set up so that $o \perp\!\!\!\perp h \mid a, i$ is a reasonable assum
- ▶ Reframe dialogue as 'asking about features' for item selection
- ▶ Convert language to and from item features

# Citations I