Entailment and Commonsense Reasoning in NLP

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The brown fox was chasing the chicken until its tail got stuck in the fence.
The brown fox was chasing the chicken until its tail got stuck in the fence.
The brown fox was chasing the chicken until its tail got stuck in the fence.
The brown fox was chasing the chicken until its wing got stuck in the fence.
The brown fox was chasing the chicken until its wing got stuck in the fence.
The brown fox was chasing the chicken until its wing got stuck in the fence.
The brown fox was chasing the chicken until its tail got stuck in the fence.

The brown fox was chasing the chicken until its wing got stuck in the fence.
• For inferring the correct referent of the pronoun, one has to know basic facts such as
  • brown foxes have tails
  • chickens have wings
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These facts are so basic for humans that they are often not recorded in written texts.

- Googling “brown foxes have tails” (or variants) yields 0 hits
Basic facts can often be deduced from more general statements

All canids\(^1\) have tails

All brown foxes have tails

\(^1\) biological family containing dogs, wolves, foxes, …
Concepts for systematic deduction

1. **Entailment**

   Sentence $A$ entails sentence $B$ iff whenever $A$ is true, $B$ is also true.
Concepts for systematic deduction

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Sentence $A$ entails sentence $B$ iff whenever $A$ is true, $B$ is also true

Every student danced $\implies$ Every Swedish student danced
Concepts for systematic deduction

2. Types of adjectives
Concepts for systematic deduction

2. **Types of adjectives**

- subsective

\[
\text{skillful violinist} \subseteq \text{violinist}
\]
2. **Types of adjectives**

**subsective**

- **skillful** violinist

  \[
  \text{[skillful violinist]} \subseteq \text{[violinist]}
  \]

**non-subsective**

- **alleged spy**

  \[
  \text{[alleged spy]} \not\subseteq \text{[spy]}
  \]
Concepts for systematic deduction

3. **Monotonicity of quantifiers**

Quantifiers that are upward monotone in their first argument

Some A X \(\Rightarrow\) Some B X
Concepts for systematic deduction

3. **Monotonicity of quantifiers**

Quantifiers that are upward monotone in their first argument

Some poodles bark

$\Rightarrow$ Some dogs bark
3. **Monotonicity of quantifiers**

Quantifiers that are downward monotone in their first argument:

$$\forall B X \Rightarrow \forall A X$$
3. **Monotonicity of quantifiers**

Quantifiers that are downward monotone in their first argument

- All dogs bark $\Rightarrow$ All poodles bark
Ingredients for systematic deduction

• some basic facts (e.g., all canids have tails) in a database

(Angeli and Manning, 2013; Nayak et al., 2014)
Ingredients for systematic deduction

- some basic facts (e.g., all canids have tails) in a database
- a list of subsective or list of non-subsective adjectives

(Angeli and Manning, 2013; Nayak et al., 2014)
Ingredients for systematic deduction

- some basic facts (e.g., all canids have tails) in a database
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Ingredients for systematic deduction

- some basic facts (e.g., all canids have tails) in a database
- a list of subsective or list of non-subsective adjectives
- a noun hierarchy (e.g., poodle $\subseteq$ dog) such as WordNet
- a list of quantifiers and their monotonicity properties

(Angeli and Manning, 2013; Nayak et al., 2014)
Procedure

- When we have a sentence with a downward monotone quantifier, we can repeatedly replace the first argument with something more specific

  All **canids** have tails

  (Angeli and Manning, 2013; Nayak et al., 2014)
Procedure

• When we have a sentence with a downward monotone quantifier, we can repeatedly replace the first argument with something more specific

All **canids** have tails

All **dogs** have tails

(Angeli and Manning, 2013; Nayak et al., 2014)
Procedure

• When we have a sentence with a downward monotone quantifier, we can repeatedly replace the first argument with something more specific

\[
\text{All canids have tails} \\
\downarrow \\
\text{All dogs have tails}
\]

(Angeli and Manning, 2013; Nayak et al., 2014)
Procedure

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  All **canids** have tails

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Procedure

- When we have a sentence with a downward monotone quantifier, we can repeatedly replace the first argument with something more specific

  All *canids* have tails

  All *foxes* have tails

(Angeli and Manning, 2013; Nayak et al., 2014)
Procedure

- When we have a sentence with a downward monotone quantifier, we can repeatedly replace the first argument with something more specific:

  \[
  \text{All canids have tails}
  \]
  \[
  \Downarrow
  \]
  \[
  \text{All foxes have tails}
  \]

(Angeli and Manning, 2013; Nayak et al., 2014)
Procedure

• When we have a sentence with a downward monotone quantifier, we can repeatedly replace the first argument with something more specific

All \textit{canids} have tails
\Downarrow
All \textit{foxes} have tails

All \textit{brown foxes} have tails

(Angeli and Manning, 2013; Nayak et al., 2014)
Procedure

- When we have a sentence with a downward monotone quantifier, we can repeatedly replace the first argument with something more specific.

  All *canids* have tails
  ↓
  All *foxes* have tails
  ↓
  All *brown foxes* have tails

  (Angeli and Manning, 2013; Nayak et al., 2014)
Procedure

• Whenever we find such an entailment path, we can conclude that the first statement entails all the statements along the path
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• This allows for a systematic deduction of commonsense facts from general facts

