Interpretation as Abduction

Paper by Hobbs et al. (1988)
Speaker: Sophie Henning

Seminar: Formal Methods in Pragmatics

11.05.2017

What is interpretation of sentences in discourse?

- Provide the best explanation of why the sentences would be true

What is interpretation of sentences in discourse?

- Provide the best explanation of why the sentences would be true
- *Derive the logical form of the sentence,*
  together with the constraints that predicates impose on their arguments,
  allowing for coercions,
  Merging redundancies where possible,
  Making assumptions where necessary.

Private and mutual beliefs

private beliefs	**mutual beliefs**
new information	given information (axioms)
$\rightarrow$ make assumptions	$\rightarrow$ derive logical form

- Axioms:

Private and mutual beliefs

private beliefs	**mutual beliefs**
new information	given information (axioms)
$\rightarrow$ make assumptions	$\rightarrow$ derive logical form

- Axioms:
  - C_1 *is a starting air compressor*

Private and mutual beliefs

private beliefs	**mutual beliefs**
new information	given information (axioms)
$\rightarrow$ make assumptions	$\rightarrow$ derive logical form

- Axioms:
  - C_1 *is a starting air compressor*
  - *A starting air compressor is a compressor*

Private and mutual beliefs

private beliefs	**mutual beliefs**
new information	given information (axioms)
$\rightarrow$ make assumptions	$\rightarrow$ derive logical form

- Axioms:
  - C_1 *is a starting air compressor*
  - *A starting air compressor is a compressor*
- Merge redundancies from private and mutual beliefs
  $\rightarrow$ minimal (best) interpretation

Four pragmatic problems

Disengaged compressor after lube-oil alarm.

1. **Reference resolution**: identify *compressor* and *alarm*

Four pragmatic problems

Disengaged compressor after lube-oil alarm.

1. **Reference resolution**: identify *compressor* and *alarm*
2. **Interpretation of compound nominals**: What is the implicit relation between *lube-oil* and *alarm*?

Four pragmatic problems

Disengaged compressor after lube-oil alarm.

1. **Reference resolution**: identify *compressor* and *alarm*
2. **Interpretation of compound nominals**: What is the implicit relation between *lube-oil* and *alarm*?
3. **Resolution of (some kind of) syntactic ambiguity**: What does *after lube-oil alarm* modify? *Compressor* or *disengaged*?

Four pragmatic problems

Disengaged compressor after lube-oil alarm.

1. **Reference resolution**: identify *compressor* and *alarm*
2. **Interpretation of compound nominals**: What is the implicit relation between *lube-oil* and *alarm*?
3. **Resolution of (some kind of) syntactic ambiguity**: What does *after lube-oil alarm* modify? *Compressor* or *disengaged*?
4. **Metonymy resolution**: *After* requires an event or condition $\rightarrow$ coerce *lube-oil alarm* into *the sounding of the lube-oil alarm*

Four pragmatic problems

Disengaged compressor after lube-oil alarm.

1. **Reference resolution**: identify *compressor* and *alarm*
2. **Interpretation of compound nominals**: What is the implicit relation between *lube-oil* and *alarm*?
3. **Resolution of (some kind of) syntactic ambiguity**: What does *after lube-oil alarm* modify? *Compressor* or *disengaged*?
4. **Metonymy resolution**: *After* requires an event or condition $\rightarrow$ coerce *lube-oil alarm* into *the sounding of the lube-oil alarm*

- 1.-3. can be solved by deriving the logical form

Four pragmatic problems

Disengaged compressor after lube-oil alarm.

1. **Reference resolution**: identify *compressor* and *alarm*
2. **Interpretation of compound nominals**: What is the implicit relation between *lube-oil* and *alarm*?
3. **Resolution of (some kind of) syntactic ambiguity**: What does *after lube-oil alarm* modify? *Compressor* or *disengaged*?
4. **Metonymy resolution**: *After* requires an event or condition $\rightarrow$ coerce *lube-oil alarm* into *the sounding of the lube-oil alarm*

- 1.-3. can be solved by deriving the logical form
- 4. can be solved by also deriving the constraints predicates impose on their arguments and allowing coercions.

Reference resolution

Disengaged compressor after lube-oil alarm.

Identify *compressor* and *alarm*

- We have to prove: $(\exists c)compressor(c)$

Reference resolution

Disengaged compressor after lube-oil alarm.

Identify *compressor* and *alarm*

- We have to prove: $(\exists c)compressor(c)$
- With axioms:

  we can prove that *compressor* refers to C_1.

Reference resolution

Disengaged compressor after lube-oil alarm.

Identify *compressor* and *alarm*

- We have to prove: $(\exists c)\mathit{compressor}(c)$
- With axioms:
  - C_1 *is a starting air compressor*

  we can prove that *compressor* refers to C_1.

Reference resolution

Disengaged compressor after lube-oil alarm.

Identify *compressor* and *alarm*

- We have to prove: $(\exists c)\mathit{compressor}(c)$
- With axioms:
  - C_1 *is a starting air compressor*
  - *A starting air compressor is a compressor*

  we can prove that *compressor* refers to C_1.

Reference resolution

Disengaged compressor after lube-oil alarm.

Identify *compressor* and *alarm*

- We have to prove: $(\exists c)compressor(c)$
- With axioms:
  - C_1 *is a starting air compressor*
  - *A starting air compressor is a compressor*

  we can prove that *compressor* refers to C_1.
- In general: definite NPs refer to already known entities, indefinite ones to new entities.

Reference resolution

Disengaged compressor after lube-oil alarm.

Identify *compressor* and *alarm*

- We have to prove: $(\exists c)\mathit{compressor}(c)$
- With axioms:
  - C_1 *is a starting air compressor*
  - *A starting air compressor is a compressor*

  we can prove that *compressor* refers to C_1.
- In general: definite NPs refer to already known entities, indefinite ones to new entities.
- In casualty reports: most NPs have no determiner
  Retained oil sample and filter for future analysis.

Interpretation of compound nominals

Disengaged compressor after lube-oil alarm.

What is the implicit relation between *lube-oil* and *alarm*?

- Find two entities a and o with an implicit relation nn and prove $(\exists o, a, nn) lube - oil(o) \wedge alarm(a) \wedge nn(o, a)$

Interpretation of compound nominals

Disengaged compressor after lube-oil alarm.

What is the implicit relation between *lube-oil* and *alarm*?

- Find two entities a and o with an implicit relation nn and prove $(\exists o, a, nn) lube - oil(o) \wedge alarm(a) \wedge nn(o, a)$
- Treating nn as a predicate variable: relation between the two nouns can be anything
  $\lambda x, y[y \textit{ sounds if pressure of } x \textit{ drops too low}]$

Interpretation of compound nominals

Disengaged compressor after lube-oil alarm.

What is the implicit relation between *lube-oil* and *alarm*?

- Find two entities a and o with an implicit relation nn and prove $(\exists o, a, nn) lube - oil(o) \wedge alarm(a) \wedge nn(o, a)$
- Treating nn as a predicate variable: relation between the two nouns can be anything
  $\lambda x, y[y \textit{ sounds if pressure of } x \textit{ drops too low}]$
- First-order simulation: treat nn as a predicate constant
  $(\forall x, y) part(y, x) \supset nn(x, y)$

Resolution of syntactic ambiguity

Disengaged compressor after lube-oil alarm.

What does *after lube-oil alarm* modify? *Compressor* or *disengaged*?

- Convert syntactic ambiguity into constrained coreference problems:
  $(\exists ...e, c, y, a...)... \wedge after(y, a) \wedge y \in \{c, e\} \wedge ...$

Metonymy resolution

Disengaged compressor after lube-oil alarm.

After requires an event or condition $\rightarrow$ coerce *lube-oil alarm* into *the sounding of the lube-oil alarm*

- Replace explicit arguments by "coercion variables":
  $(\exists ... k_1, k_2, y, a, rel_1, rel_2, ...) ... \wedge after(k_1, k_2) \wedge event(k_1) \wedge rel_1(k_1, y) \wedge event(k_2) \wedge rel_2(k_2, a) \wedge ...$

Metonymy resolution

Disengaged compressor after lube-oil alarm.

After requires an event or condition $\rightarrow$ coerce *lube-oil alarm* into *the sounding of the lube-oil alarm*

- Replace explicit arguments by "coercion variables":
  $(\exists ... k_1, k_2, y, a, rel_1, rel_2, ...) ... \wedge after(k_1, k_2) \wedge event(k_1) \wedge rel_1(k_1, y) \wedge event(k_2) \wedge rel_2(k_2, a) \wedge ...$
- This again uses predicate variables (e.g. rel_1), we want to use a predicate constant *rel* to form axioms like

Metonymy resolution

Disengaged compressor after lube-oil alarm.

After requires an event or condition $\rightarrow$ coerce *lube-oil alarm* into *the sounding of the lube-oil alarm*

- Replace explicit arguments by "coercion variables":
  $(\exists ... k_1, k_2, y, a, rel_1, rel_2, ...) ... \wedge after(k_1, k_2) \wedge event(k_1) \wedge rel_1(k_1, y) \wedge event(k_2) \wedge rel_2(k_2, a) \wedge ...$
- This again uses predicate variables (e.g. rel_1), we want to use a predicate constant *rel* to form axioms like
  - $(\forall x) rel(x, x)$

Metonymy resolution

Disengaged compressor after lube-oil alarm.

After requires an event or condition $\rightarrow$ coerce *lube-oil alarm* into *the sounding of the lube-oil alarm*

- Replace explicit arguments by "coercion variables":
  $(\exists ... k_1, k_2, y, a, rel_1, rel_2, ...) ... \wedge after(k_1, k_2) \wedge event(k_1) \wedge rel_1(k_1, y) \wedge event(k_2) \wedge rel_2(k_2, a) \wedge ...$
- This again uses predicate variables (e.g. rel_1), we want to use a predicate constant *rel* to form axioms like
  - $(\forall x) rel(x, x)$
  - $(\forall x, y) part(y, x) \supset rel(x, y)$

Metonymy resolution

Disengaged compressor after lube-oil alarm.

After requires an event or condition $\rightarrow$ coerce *lube-oil alarm* into *the sounding of the lube-oil alarm*

- Replace explicit arguments by "coercion variables":
  $(\exists ... k_1, k_2, y, a, rel_1, rel_2, ...) ... \wedge after(k_1, k_2) \wedge event(k_1) \wedge rel_1(k_1, y) \wedge event(k_2) \wedge rel_2(k_2, a) \wedge ...$
- This again uses predicate variables (e.g. rel_1), we want to use a predicate constant *rel* to form axioms like
  - $(\forall x) rel(x, x)$
  - $(\forall x, y) part(y, x) \supset rel(x, y)$
  - $(\forall x, e) function(e, x) \supset rel(e, x)$

All together

Disengaged compressor after lube-oil alarm.

- To solve all these problems, the following expression has to be derived:
  $(\exists e, x, c, k_1, k_2, y, a, o) Past(e) \wedge disengage'(e, x, c) \wedge compressor(c) \wedge after(k_1, k_2) \wedge event(k_1) \wedge rel(k_1, y) \wedge y \in \{c, e\} \wedge event(k_2) \wedge rel(k_2, a) \wedge alarm(a) \wedge nn(o, a) \wedge lube-oil(o)$

Assume things if necessary

- What to do if we cannot derive parts of the expression?

Assume things if necessary

- What to do if we cannot derive parts of the expression?
- Assume these parts!

Assume things if necessary

- What to do if we cannot derive parts of the expression?
- Assume these parts!
- Assign a cost of assuming it to each of the atoms

Assume things if necessary

- What to do if we cannot derive parts of the expression?
- Assume these parts!
- Assign a cost of assuming it to each of the atoms
  - Definite NPs: expensive

Assume things if necessary

- What to do if we cannot derive parts of the expression?
- Assume these parts!
- Assign a cost of assuming it to each of the atoms
  - Definite NPs: expensive
  - Indefinite NPs: cheap

Assume things if necessary

- What to do if we cannot derive parts of the expression?
- Assume these parts!
- Assign a cost of assuming it to each of the atoms
  - Definite NPs: expensive
  - Indefinite NPs: cheap
  - Verbs: rather cheap

Abduction

- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$

Abduction

- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$
- This is **not valid**!

Abduction

- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$
- This is **not valid**!
- We need other criteria to choose among possibilities:

Abduction

- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$
- This is **not valid**!
- We need other criteria to choose among possibilities:
  - **Consistency** of $p(A)$ with the rest of what one knows

Abduction

- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$
- This is **not valid**!
- We need other criteria to choose among possibilities:
  - **Consistency** of $p(A)$ with the rest of what one knows
  - **Simplicity**: $p(A)$ should be as small as possible

Abduction

- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$
- This is **not valid**!
- We need other criteria to choose among possibilities:
  - **Consistency** of $p(A)$ with the rest of what one knows
  - **Simplicity**: $p(A)$ should be as small as possible
  - **Consilience**: $q(A)$ should be as big as possible

Abduction

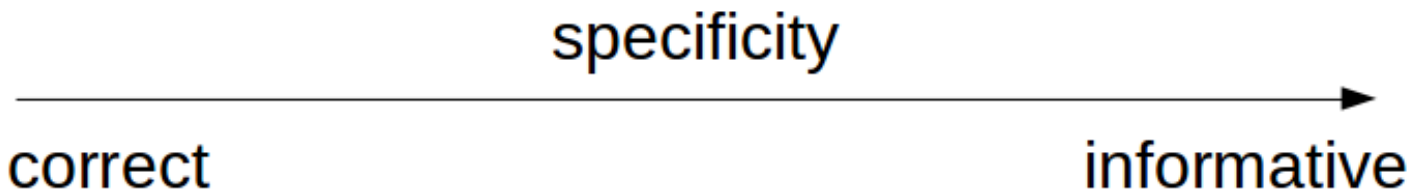
- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$
- This is **not valid**!
- We need other criteria to choose among possibilities:
  - **Consistency** of $p(A)$ with the rest of what one knows
  - **Simplicity**: $p(A)$ should be as small as possible
  - **Consilience**: $q(A)$ should be as big as possible
- **Informativeness-correctness tradeoff**:

Abduction

- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$
- This is **not valid**!
- We need other criteria to choose among possibilities:
  - **Consistency** of $p(A)$ with the rest of what one knows
  - **Simplicity**: $p(A)$ should be as small as possible
  - **Consilience**: $q(A)$ should be as big as possible
- **Informativeness-correctness tradeoff**:
  - Previously in AI (previous to 1988): most specific abduction favored

Abduction

- Principle: conclude $p(A)$ from $(\forall x)p(x) \supset q(x)$ and $q(a)$
- This is **not valid**!
- We need other criteria to choose among possibilities:
  - **Consistency** of $p(A)$ with the rest of what one knows
  - **Simplicity**: $p(A)$ should be as small as possible
  - **Consilience**: $q(A)$ should be as big as possible
- **Informativeness-correctness tradeoff**:
  - Previously in AI (previous to 1988): most specific abduction favored
  - NLP: least specific abduction



How to state the axioms

- $P_1^{w_1} \wedge P_2^{w_2} \supset Q$
  Cost of assuming Q: c
  Cost of assuming P_1: $w_1 c$
  Cost of assuming P_2: $w_2 c$

How to state the axioms

- $P_1^{w_1} \wedge P_2^{w_2} \supset Q$
  Cost of assuming Q: c
  Cost of assuming P_1: $w_1 c$
  Cost of assuming P_2: $w_2 c$
- Effect of w_1 and w_2:
  if $w_1 + w_2 < 1$: most specific abduction favored
  if $w_1 + w_2 > 1$: least specific abduction favored

Use semantic information

- Assign weight according to the semantic contribution of each conjunct
  $(\forall x) car(x)^{0.8} \wedge no - top(x)^{0.4} \supset convertible(x)$

Use semantic information

- Assign weight according to the semantic contribution of each conjunct
  $(\forall x) car(x)^{0.8} \wedge no - top(x)^{0.4} \supset convertible(x)$
- Use superset information:
  Flow obstructed. Metal particles in lube oil filter.
  To prove: $(\exists x) lube - oil(x)$

Use semantic information

- Assign weight according to the semantic contribution of each conjunct
  $(\forall x) car(x)^{0.8} \wedge no - top(x)^{0.4} \supset convertible(x)$
- Use superset information:
  Flow obstructed. Metal particles in lube oil filter.
  To prove: $(\exists x) lube - oil(x)$
  - An axiom $(\forall x) fluid(x) \supset lube - oil(x)$ would help to establish the identity, but is not true.

Use semantic information

- Assign weight according to the semantic contribution of each conjunct
  $(\forall x) car(x)^{0.8} \wedge no - top(x)^{0.4} \supset convertible(x)$
- Use superset information:
  Flow obstructed. Metal particles in lube oil filter.
  To prove: $(\exists x) lube - oil(x)$
  - An axiom $(\forall x) fluid(x) \supset lube - oil(x)$ would help to establish the identity, but is not true.
  - Convert the axiom into a biconditional:
    $(\forall x) fluid(x) \wedge etc_1(x) \equiv lube - oil(x)$

Controlling abduction: type hierarchy

- Unconstrained consistency checking may take a long time

Controlling abduction: type hierarchy

- Unconstrained consistency checking may take a long time
- Type hierarchy: Eliminate possible assumptions that are likely to result in an inconsistency.
  $(\forall x)\mathit{pressure}(x) \supset \neg \mathit{lube} - \mathit{oil}(x)$

Controlling abduction: type hierarchy

- Unconstrained consistency checking may take a long time
- Type hierarchy: Eliminate possible assumptions that are likely to result in an inconsistency.
  $(\forall x)\mathit{pressure}(x) \supset \neg \mathit{lube} - \mathit{oil}(x)$
- Here: Rather used as a heuristic about what someone would or would not say.

Summary

- Derive logical forms in order to interpret sentences

Summary

- Derive logical forms in order to interpret sentences
- Abduction helps us deriving these forms using axiomatic knowledge

Summary

- Derive logical forms in order to interpret sentences
- Abduction helps us deriving these forms using axiomatic knowledge
- This might lead to wrong interpretations

Summary

- Derive logical forms in order to interpret sentences
- Abduction helps us deriving these forms using axiomatic knowledge
- This might lead to wrong interpretations
- Limit number of possibilities with a type hierarchy

Discussion

1. Hobbs et al. say that the minimal interpretation of a sentence is its best interpretation. To prevent someone from argueing that *Close the window* as the preferred interpretation of *It's cold in here* is not the minimal interpretation, they add the fact that the best interpretation is the minimal one which is coherent with the interests of the speaker. How could we determine the interests of the speaker?