Language and logic: reasoning in NPL tasks

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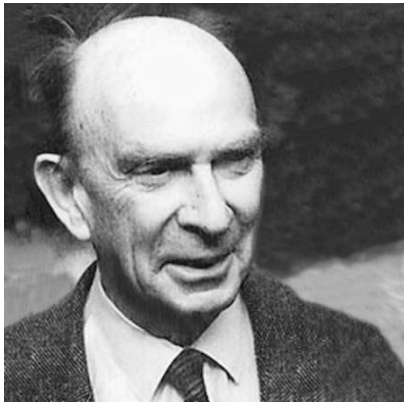
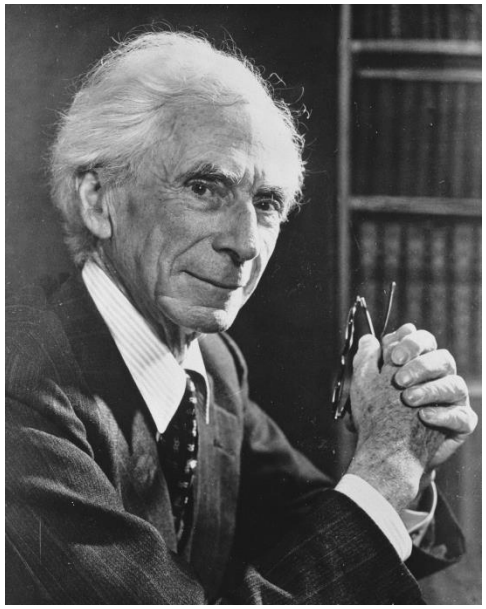
A parable

Strawson and Russell



- Strawson, 1950:
  - *"Neither Aristotelian nor Russellian rules give the exact logic of any expression of ordinary language; for ordinary language has no exact logic."*

- Russell 1957:
  - *"I am totally unable to see any validity whatever in any of Mr. Strawson's arguments. … I agree, however, with Mr. Strawson's statement that ordinary language has no logic."*



Natural vs formal language

- [John] sleeps sleep(John)
- Direct correspondence between natural and formal languages

- [All students] sleep $\forall x[student(x) \rightarrow sleep(x)]$
- Which part of the statement on the right corresponds to the noun phrase “All students”?
- No part
- Hence – natural language is not logical

Richard Montague

- Montague was a mathematician an logician; he did not participate in linguistics wars
- But he was annoyed that so much noise was going on around the difference between formal and informal languages
- That's why one day he sat down to proceed with *"rather easy and not very important"* task – to show that natural language can be interpreted formally
- And he succeeded, though it turned not so easy

Natural language as formal

- [All students] sleep all_students(sleep)
- all_students(P) = $\forall x[student(x) \rightarrow P(x)]$
- all_students(sleep) = $\forall x[student(x) \rightarrow sleep(x)]$
- Hence – natural language allows formal interpretation

- [John] sleeps John_property(sleep)
- John_property(P) = P(John)
- John_property(sleep) = sleep(John)

Truth conditions and beyond

- The meaning of a sentence is its truth conditions (as in mathematics)
- Interpretation in a model:
  - ‘John’ denotes an individual from the universe of discourse
  - ‘sleep’ denotes a subset of the universe of discourse
- However:
  - Sentence is more then just an assertion of the truth of a proposition
  - Sentence is *a message, an information transmission* from the speaker to the hearer

Language and logic again

- Logical operators in natural language work differently then in formal logic
- Existential and universal quantifiers:
  - Some students came (not all)
- Exclusive “or”:
  - She has a dog or a cat (but not both)
- Two-way implication:
  - If it is raining, I take an umbrella (and if it is not?)
- Non-commutative "and":
  - she got married and had a baby (and not vice versa)
- Is the logic of language different (is it non-logical)?

Herbert Paul Grice

- Paul Grice. Logic and Conversation (1975)
- The meaning of operators in natural language does not differ from their meaning in formal logic
- But we have to distinguish what is said (semantics) and which conclusions were drawn from it (pragmatics)
- Grice introduced the notion of implicature

Cooperative principle

- Dialogue is not a set of unrelated replicas
- Usually participants jointly follow the common purpose of the dialogue or at least mutually accepted direction
- Main principle: make your contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged
- The principle is realized through four maxims

Gricean maxims

- Maxim of quantity:
  - Make your contribution as informative as is required
  - Do not make your contribution more informative than is required
- Maxim of quality:
  - Do not say what you believe is false.
  - Do not say that for which you lack adequate evidence

Gricean maxims

- Maxim of relation:
  - Be relevant
- Maxim of manner:
  - Avoid obscurity of expression
  - Avoid ambiguity
  - Be brief
  - Be orderly
- Maxims operate not only in conversation but in any cooperative activity

Conversational implicatures

- Conversational implicatures appear because we expect the interlocutor to follow the principle of cooperation
- They are not a logical consequence of what is said
- They can be cancelled by a subsequent discourse

Examples

- Maxim of quantity
  - Some students came (in fact all of them)
  - She has a dog or a cat (or may be both)

- Maxim of manner
  - she got married and had a baby (but not in that order)

Not following the maxims

- The speaker can:
  - Silently violate maxims. Then he takes responsibility for the "deception".
  - Opt out of following the maxim. «I cannot say more».
  - Violate one maxim trying to following the other when they contradict each other
  - Explicitly flout the maxims, thus creating a new implicature

More examples

- – I am out of gas.
  - – There is a gas station round the corner (implicature: it is open)
- – Where does Mary live?
  - – Somewhere in the South of France (contradiction of the maxims of quality and quantity)
- – At war as at war (flouting the maxim of quantity)
- – John is a great friend (irony, flouting the maxim of quality).

Winograd Schemas

- Proposed by Hector Levesque in 2011
- The trophy doesn't fit in the brown suitcase because **it**'s too *big*. What is too *big*?
  - the trophy
  - the suitcase
- Joan made sure to thank Susan for all the help **she** had *given*. Who had *given* the help?
  - Joan
  - Susan
- Terry Winograd provided the first example in 1970

Winograd Schema Structure

- Anaphora resolution problem
- There are two potential antecedents in the sentence
- Linguistic features, collocation statistics and selectional restrictions do not help much
- Changing a special word in the sentence reverts the correct answer (*big -> small*)
- The trophy doesn't fit in the brown suitcase because **it**'s too *small*. What is too *small*?
  - the trophy
  - the suitcase

Commonsense Knowledge

- People are good on Windograd Schemas
- Tests show 91-92% correct answers.
- What is required to get the right answer?
- Understanding of the verb ‘fit’
  - if A fits into B then A must be smaller than B.
- Understanding of the connective ‘because’
  - Changing it to ‘in spite of’ also reverts the answer.
- Implicit information must be extracted from the text to pass the test

Competition Results

- Six solutions of four teams where presented:

Contestant	Number correct	Percentage correct
Patrick Dhondt	27	45%
Denis Robert	19	31.666%
Nicos Issak	29	48.33%
Quan Liu (1)	28	46.9% (48.33)*
Quan Liu (2)	29	48.33% (58.33)*
Quan Liu (3)	27	45% (58.33)*

- Random answering could yield 45%

Indefinite descriptions

- Are indefinite descriptions referential?
- Russell assumed the existential quantifier
  - A dog came in. $\exists x(\text{dog}(x) \,\&\, \text{came-in}(x))$
- Arguments against referential view:
  - John is friends with a dog, and Mary is friends with a dog
  - It is not the case that a dog came in
  - Every child owns a dog

Indefinite descriptions

- But what about such examples as:
  - A dog came in. *It* lay down under the table.
- Extend the scope of the quantifier (Geach):
  - ∃x(dog(x) & x came in & x lay down)
- But:
  - A man fell over the edge. – *He* didn't fall; he jumped
  - A dog came in. – What did *it* do next?

Indefinite descriptions

- Pronouns are disguised definite descriptions (Evans E-type pronouns)
  - A dog came in. It [the dog that came in] lay down under the table.
- They assume uniqueness of definite descriptions, but:
  - Everybody who bought *a sage plant* here bought *eight others* along with *it*.

Discourse referents

- Karttunen proposed a notion of discourse referents
- Unlike real referents they appear as discourse progresses (in interlocutors' minds)
- A discursive referent may lack a real referent
- One real referent can correspond to several discourse referents

Familiarity theory

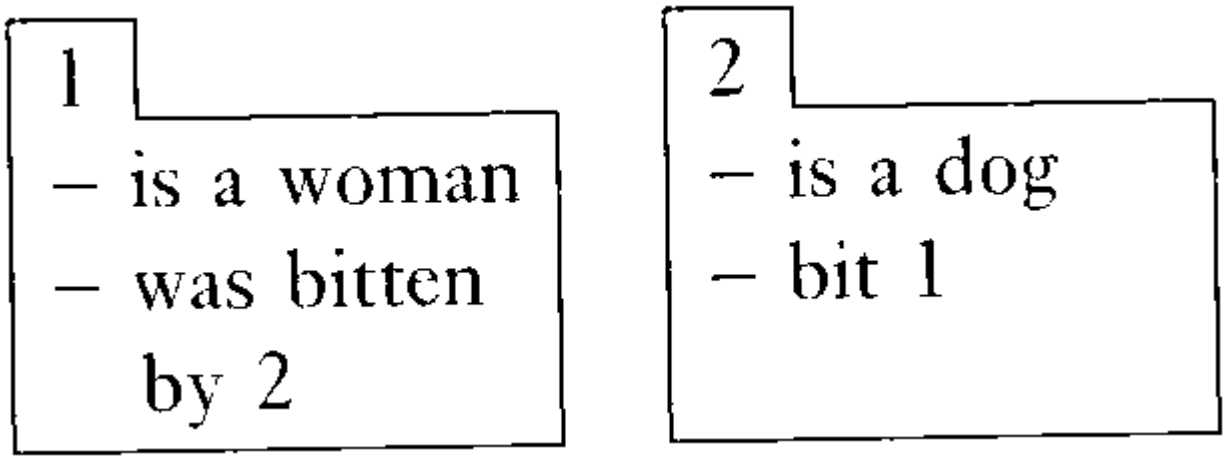
- Definite descriptions are not unique but just familiar to interlocutors
- Heim makes use of discourse referents to support her theory:
  - John came, and so did Mary. *One of them* brought a cake.
- One of them is a definite description, but it does not introduce new referent, just a new *discourse* referent

File Change Semantics

- Indefinite descriptions introduce a new variable (discourse referent)
- Definite descriptions refer to an existing variable (discourse referent)
- Each discourse referent corresponds to a file card in the internal file of interlocutors

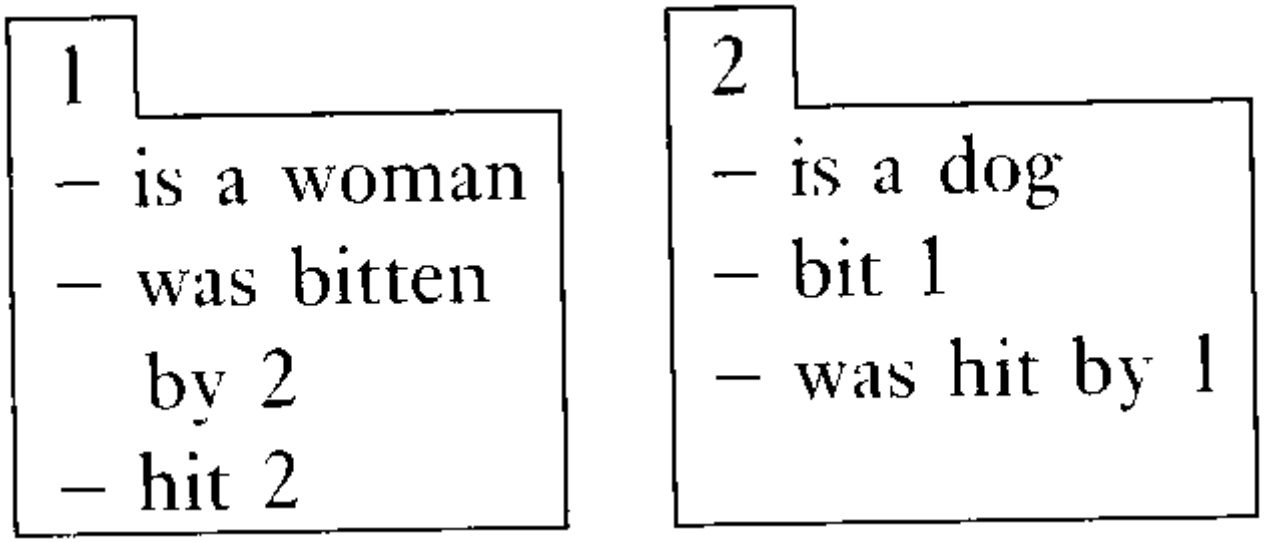
File Change Semantics

- *A woman was bitten by a dog*



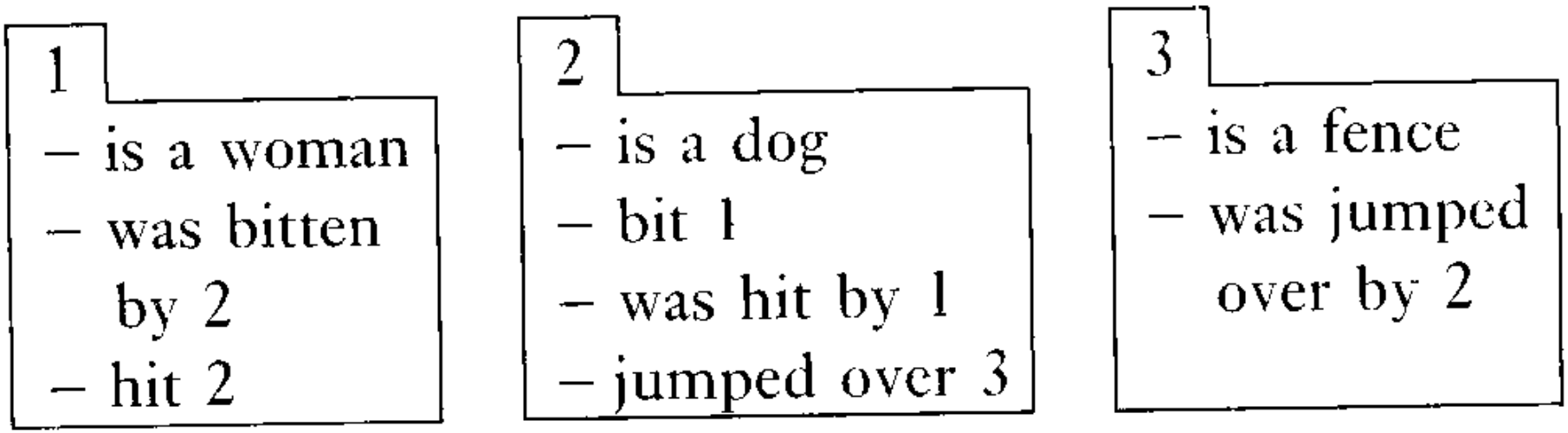
File Change Semantics

- *A woman was bitten by a dog*
- *She hit it*



File Change Semantics

- *A woman was bitten by a dog*
- *She hit it*
- *It jumped over the fence*

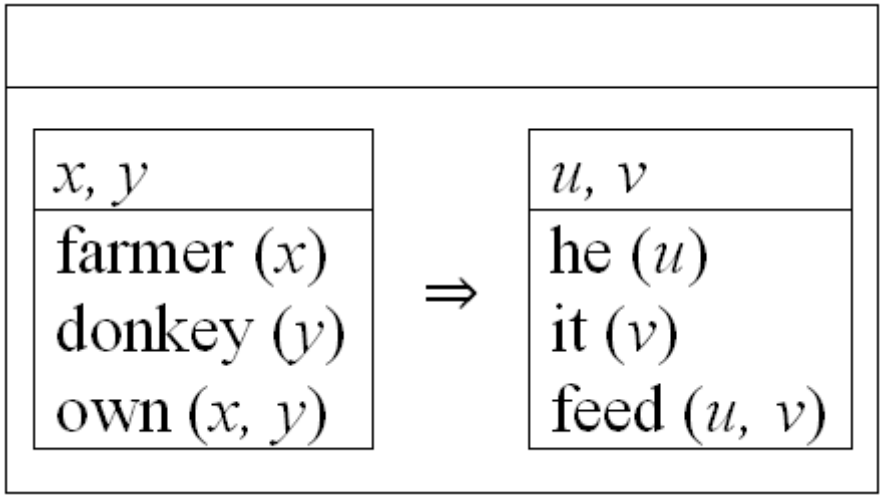


Truth conditions

- The entire file of cards is true is there is a set of real referents which correspond to cards
- A single sentence is true if adding it to a true file result in a true file
- But what is more important for a sentence is not its truth conditions, but its file change potential

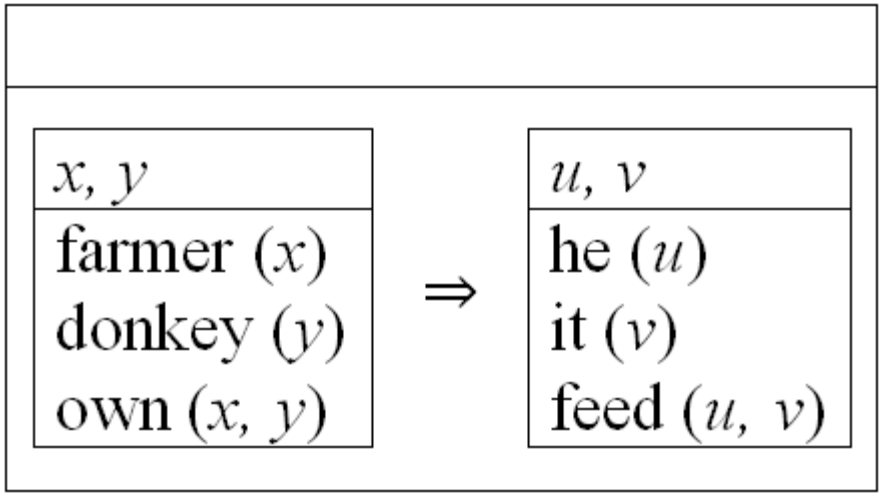
Discourse Representation Theory

- DRT is a dynamic semantic theory (Kamp 1981)
  - Employs a semantic representation called DRS
  - A DRS consists of discourse referents and conditions
  - For complex sentences, a DRS can contain sub-DRSs
- *If a farmer owns a donkey, he feeds it*



Anaphora resolution

- *If a farmer owns a donkey, he feeds it*



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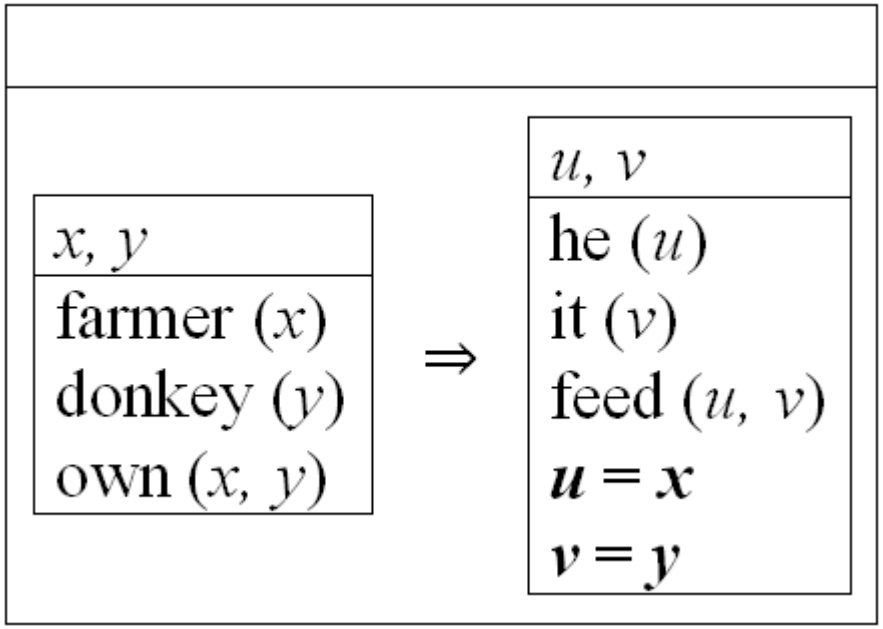
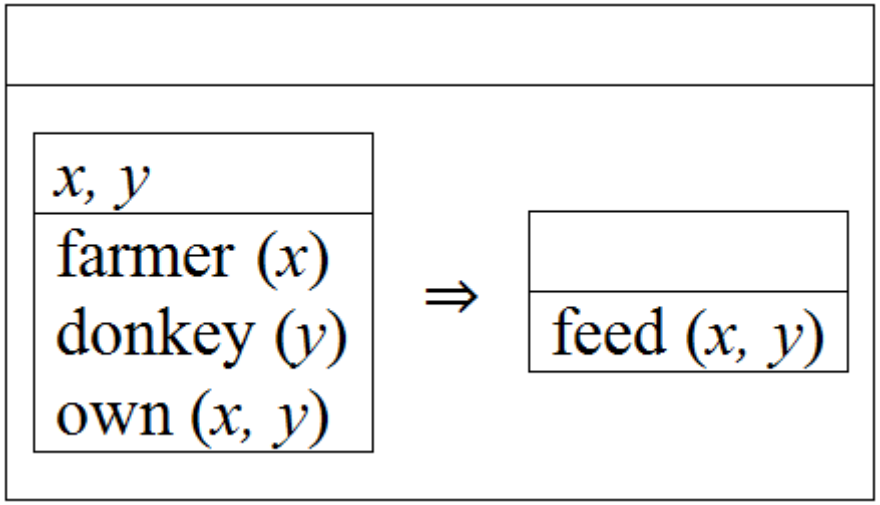


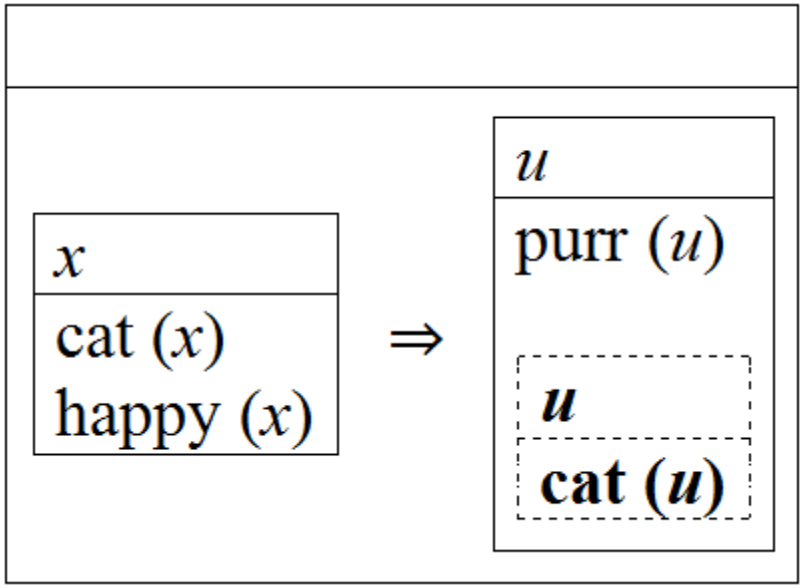
Anaphora resolution

- *If a farmer owns a donkey, he feeds it*



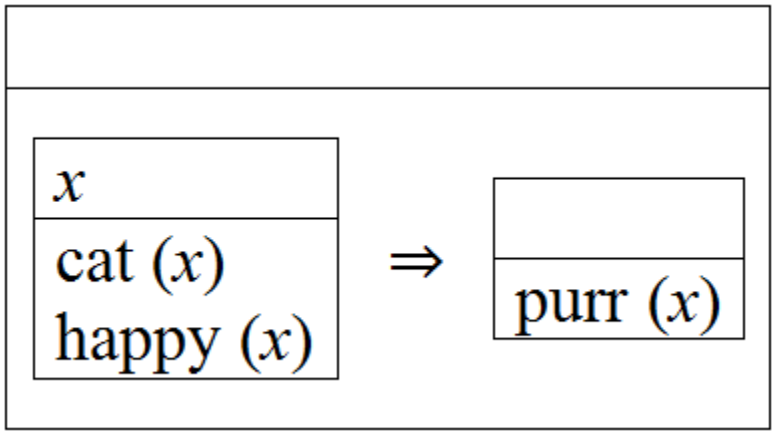
Presupposition projection

- Binding theory of presupposition (van der Sandt 1992)
  - A special sub-DRS (A-DRS) stores the presupposition content
  - A Preliminary DRS is a DRS with non-empty A-DRSs
- *If a cat is happy,* ***the cat*** *purrs*



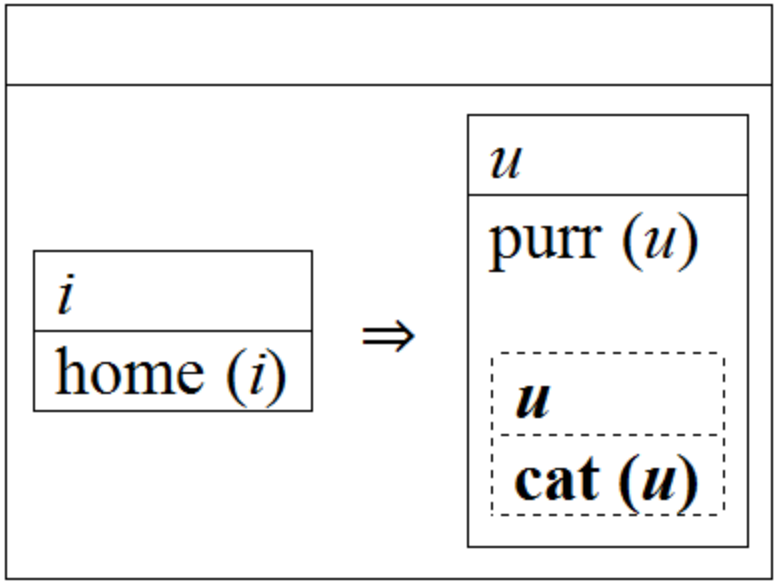
Presupposition projection

- Preliminary DRS vs Proper DRS
  - A-DRSs must be resolved – bound or accommodated higher
  - Once they are resolved, Main DRS becomes a Proper DRS
- *If a cat is happy, the cat purrs*



Presupposition accommodation

- Accommodation
  - If no antecedent is found, it can be added (accommodated)
  - This is a repair strategy
- *When I am at home, the cat purrs*



Presupposition accommodation

- Binding vs accommodation
  - Binding goes bottom-up
  - Accommodation goes top-down
- *When I am at home, the cat purrs*