Scope Alternation without Quantifier Movement

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Preamble

- Logic was invented to model the process of irrefutable argument in natural language, in contrast to rhetoric.

- It almost immediately departed from anything natural—for example by stubbornly identifying the conditional with material implication.

- The idea that there is a "Natural" logic, to which language is transparent, resurfaces from time to time, most recently in the work of Pierce, Carnap, Montague, Geach, Lakoff, Partee, and Dowty.

- It has usually worked within existing mathematical and philosophical logics, apparently due to excessive awe of model theory and/or mathematical elegance, at some cost to explanatory force.

Preamble

- The present approach turns the problem upside down.
- We assume that language is entirely transparent to a natural logic that can be inferred from its form, albeit with difficulty.
  1. All semantic categories and operations are strictly monotonic, and related rule-to-rule to (morpho)syntactic categories and operations (Klein and Sag, 1985).
  2. All language-specific information resides in the lexicon.
  3. The mechanism for syntactic projection is universal.
- There are immediate benefits for computing logical forms as a prelude for inference.

Outline

- Reasons for deriving alternating quantifier scopes from the derivational combinatorics of monotonic, monostratal grammars, rather than by movement or equivalent type-shifting.

- Using Generalized Skolem Terms in place of Existential Generalized Quantifiers.

I. The Problem of Quantifier Scope Ambiguity

- The following sentence has two readings, expressed in (2) using FOPL:

  (1) Everybody loves somebody.

- (2) a. $\forall x[person'x \rightarrow \exists y[person'y \wedge loves'yx]])$
  b. $\exists y[person'y \wedge \forall x[person'x \rightarrow loves'yx]$

- (2b) appears not to be derivable from the simple combinatorics of grammatical derivation, in which the subject commands the object..

Approaches to Quantifier Scope Ambiguity

- The observation has motivated "quantifying in," (Montague 1973) "covert quantifier movement," (May 1985), and morpholexically unmotivated type-changing operations, and the dreaded "underspecification." Woods 1978; Kempson and Cormack 1981

- Instead, We should adhere to strict surface-compositionality, using nothing but the derivational combinatorics of surface grammar to deliver all and only the attested readings.

- In this endeavor, the most important point to bear in mind is that in natural language, universally quantified NPs like *everyone* and *each person do* behave like generalized quantifiers, but existentials like *someone* and *at least three people* do *not*.

Scope Alternation: The Universals

- The universal quantifiers *every* and *each* can invert scope in the strong sense of binding (unboundedly) c- or lf-commanding indefinites, subject to certain island conditions:

(3) a. Some man loves every woman
b. $\forall x[woman'\,x \Rightarrow \exists y[man'\,y \wedge loves'\,x\,y]]$

- Such quantifier "movement" appears to be subject to the same "Across-the-Board" condition as *wh*-movement, as in examples like the following (Geach 1972):

(4) Every boy admires, and every girl detests, some saxophonist.

- There are only two readings, not four. (Another problem for covert quantifier movement)

Scope (Non)Alternation: The Existentials

- Existential quantifiers like *some*, *a*, and *at least/at most/exactly three* appear able to take wide scope over unboundedly c- or lf-commanding universals, and are *not* sensitive to island boundaries.

(5) Every boy knows a woman who read a (certain) book.

- However, existentials in general cannot invert scope in the strong sense of distributing over a structurally-commanding indefinite:

(6) a. Some member attended at least three rallies. (#3∃/∃3)
b. Exactly half the boys in the class kissed three girls. ($\#3\frac{1}{2}/\frac{1}{2}3$)

- Maybe existentials aren't GQs, and don't really move at all.

Deriving Scope from Grammatical Combinatorics

- We replace all existentially quantified NPs by a generalization of standard *Skolem terms*.

- Skolem terms are obtained by replacing all occurrences of a given existentially quantified variable by a term applying a unique functor to all variables bound by universal quantifiers in whose scope the existential quantifier falls.

- Such Skolem terms denote dependent "narrow-scope" indefinite individuals.

- If there are no such universal quantifiers, then the Skolem term is a constant.

- Since constants behave as if they "have scope everywhere", such terms denote nondependent "wide-scope" specific-indefinites.

Generalized Skolem Terms

- We generalize the notion of Skolem terms by analogy to generalized quantifiers by packaging the restriction p (and any associated cardinality property c) inside the functor over arguments $\mathcal{A}$, in a term of the form $sk_{p;c}^{(\mathcal{A})}$

- For indefinites, we can forget about cardinality c, and think of them simply as $sk_{p}^{(\mathcal{A})}$

- The ambiguity of (1) can be expressed by the following two logical forms, which differ only in the generalized skolem terms $sk_{person'}^{(x)}$ (denoting a dependent or "narrow-scope" beloved) and $sk_{person'}$, a Skolem constant.

(7) a. $\forall x[person'x \rightarrow loves' sk_{person'}^{(x)} x)]$
b. $\forall x[person'x \rightarrow loves' sk_{person'} x)]$

The Model Theory (Steedman 2012 with S. Isard)

- We need an explicit model theory because Generalized Skolem Terms are first class citizens of the logic, rather than being derived from existentials via prenex normal form. They need to carry information about their scope with them, to avoid problems arising from their interaction with negation.

(8) a. Some farmer owns no donkey.
b. $\neg_i owns' -_i sk_{donkey'} + sk_{farmer'}$

- This will come in handy for monotone inference in QA and Text Inference.
- The model theory also treats implication as $\neg P \vee (P \wedge Q)$, rather than material implication.
- This amounts to building strict implication into the model theory, and is forced by the duplication of Skolem terms in donkey sentences.

Universals ARE Generalized Quantifiers in CCG

- The universals *every* and *each* are Good Old-Fashioned generalized quantifier determiners:

(9) every, each := $NP^{\uparrow}_{3SG}/_{\diamond}N_{3SG} : \lambda p \lambda q \lambda \ldots \forall x[px \rightarrow qx \ldots]$

- $NP^{\uparrow}$ schematizes over all NP types raised over functions of the form $T|NP$, $.\lambda \ldots$ schematizes over the corresponding arguments.

This is analogous to **lexicalizing covert quantifier movement**. but there is no movement or equivalent syntactic type-lifting, only MERGE, a.k.a. unification of variables

Existentials NOT Generalized Quantifiers in CCG

- All other "quantifiers" are referential (cf. Woods 1975; VanLehn 1978; Webber 1978; Fodor and Sag 1982; Park 1996).

  (10) a, an, some := $NP^{\uparrow}_{agr}/_{\diamond}N_{agr} : \lambda p \lambda q.q(skolem' p)$

- In the present theory, existentials entirely lack quantificational senses.

II: Indefinites as Generalized Skolem Terms

- We do this by making the meaning of NPs underspecified Skolem terms of the form $skolem'\,p\,c$, (Again, p is a predicate such as $donkey'$, corresponding to the restrictor of a generalized quantifier, and c is a cardinality condition which may be null.

- We then define a notion of an environment for Skolem terms:

  (11) *The environment* $\mathcal{E}$ of an unspecified skolem term $\mathcal{T}$ is a tuple comprising all variables bound by a universal quantifier or other operator in whose structural scope $\mathcal{T}$ has been brought at the time of specification, by the derivation so far.

Indefinites as Generalized Skolem Terms

- Skolem term Specification (simplified) can then be defined as follows:

  (12) *Skolem specification* of a term t of the form $skolem'\,p\,c$ in an environment $\mathcal{E}$ yields a generalized Skolem term $sk_{p;c}^{\mathcal{E}}$, which applies a generalized Skolem functor sk_p to the tuple $\mathcal{E}$, defined as the environment of t at the time of specification, which constitutes the *arguments* of the generalized Skolem term.

- We will ignore cardinality properties c for present purposes.

- There is more to say about negation and polarity here.

Narrow-scope Saxophonist Reading

(13) Every boy admires some saxophonist

$$\frac{\text{Every boy}}{S/(S\backslash NP_{3SG}) : \lambda p.\forall y[boy'y \rightarrow py]} \quad \frac{\text{admires}}{(S\backslash NP_{3SG})/NP : admire'} \quad \frac{\text{some saxophonist}}{(S\backslash NP)\backslash((S\backslash NP)/NP) : \lambda q.q(skolem'saxophonist')}$$

$$\xrightarrow{<} S\backslash NP : admires'(skolem'saxophonist')$$

$$\xrightarrow{>} S : \forall y[boy'y \rightarrow admires'(skolem'saxophonist')y]$$

$$\cdots\cdots\cdots$$

$$S : \forall y[boy'y \rightarrow admires'\, sk^{(y)}_{saxophonist'}\, y]$$

- ***Contra* Montague and the Lambek calculi, the left-branching derivation allows the same logical form.**

That **has** to be the case, because of the Geach sentence (4) (see below).

Wide-scope Saxophonist Reading

(14) Every boy — admires — some saxophonist

$$\text{Every boy}: \; S/(S\backslash NP_{3SG}) : \lambda p.\forall y[boy'y \to py]$$

$$\text{admires}: \; (S\backslash NP_{3SG})/NP \; admires'$$

$$\text{some saxophonist}: \; (S\backslash NP)\backslash((S\backslash NP)/NP) : \lambda q.q(skolem'saxophonist') \; \dots\dots \; : \lambda q.q\, sk_{saxophonist'}$$

$$\overline{\quad S\backslash NP : admires'sk_{saxophonist'} \quad}^{<}$$

$$\overline{\quad S : \forall y[boy'y \to admires'sk_{saxophonist'}y] \quad}^{>}$$

- ***Contra* Montague and the Lambek calculi, the left-branching derivation allows the same logical form.**

Again, that **has** to be the case, because of the Geach sentence (4) (see below).

Coordination Constraints on Scope Alternation

- *SP* showed that, by contrast with distributivity, localizing quantification and Skolem terms on the NP disallows mixed readings:

- Narrow-scope saxophonist reading of (4):

(15)

$$\dfrac{\dfrac{\text{Every boy admires and every girl detests}}{S/NP : \lambda x.\forall y[boy'y \rightarrow admires'xy] \wedge \forall z[girl'z \rightarrow detests'xz]} \quad \dfrac{\text{some saxophonist}}{S\backslash(S/NP) : \lambda q.q(skolem'\,saxophonist')}}{S : \forall y[boy'y \rightarrow admires'\,(skolem'\,saxophonist')y] \wedge \forall z[girl'z \rightarrow detests'\,(skolem'\,saxophonist')z]}<$$

$$\cdots\cdots\cdots\cdots\cdots\cdots$$

$$S : \forall y[boy'y \rightarrow admires'\, sk^{(y)}_{saxophonist'}\, y] \wedge \forall z[girl'z \rightarrow detests'\, sk^{(z)}_{saxophonist'}\, z]$$

Coordination Constraints on Scope Alternation

- The same categories also yield the wide-scope saxophonist reading of (4):

(16) Every boy admires and every girl detests — some saxophonist

$$\dfrac{\dfrac{\text{Every boy admires and every girl detests}}{S/NP : \lambda x.\forall y[boy'y \rightarrow admires'xy] \wedge \forall z[girl'z \rightarrow detests'xz]} \quad \dfrac{\text{some saxophonist}}{\dfrac{S\backslash(S/NP) : \lambda q.q(skolem'saxophonist')}{: \lambda q.q\, sk_{sax}}}}{S : \forall y[boy'y \rightarrow admires'sk_{sax}y] \wedge \forall z[girl'z \rightarrow detests'sk_{sax}z]}<$$

- these are the only two readings: There are no mixed readings.

How Universals Invert Scope

- (17) Some boy admires every saxophonist

$$\frac{\text{Some boy}}{S/(S\backslash NP_{3SG}) : \lambda p.p(skolem'boy')} \quad \frac{\text{admires}}{(S\backslash NP_{3SG})/NP : \lambda x\lambda y.admires'xy} \quad \frac{\text{every saxophonist}}{(S\backslash NP)\backslash((S\backslash NP)/NP) : \lambda q.\forall x[saxophonist'x \rightarrow qx]}$$

$$\overline{S\backslash NP_{3SG} : \lambda y.\forall x[saxophonist'x \rightarrow admires'xy]}^{<}$$

$$\overline{S : \forall x[saxophonist'x \rightarrow admires'\,x\,(skolem'boy')]}^{>}$$

$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

$$S : \forall x[saxophonist'x \rightarrow admires'\,x\,sk_{boy'}^{(x)}]$$

- The SVO grammar of English means that embedded subjects in English are correctly predicted neither to extract nor to allow universals to take scope over their matrix subject in examples like the following (Cooper 1983, Farkas 2001):

Non Inversion of Embedded Subject Universals

- (18) a. *a boy who(m) [I know that]$_{S/_{\diamond}S}$ [admires some saxophonist]$_{S\backslash NP}$

  b. [Somebody knows (that)]$_{S/_{\diamond}S}$ [every boy]$_{S/(S\backslash NP)}$ [admires]$_{(S\backslash NP)/NP}$ some saxophonist.

  $\neq \forall x[boy'x \rightarrow know'(admire'sk_{saxophonist'}x)sk^{(x)}_{person'}]$

  $\neq \forall x[boy'x \rightarrow know'(admire'sk^{(x)}_{saxophonist'}x)sk^{(x)}_{person'}]$

- This sort of thing is very common in German (Kayne 1998; Bayer 1990, 1996; *SP*)

- To allow bare complement subjects to extract a quite different "antecedent governed" category $(VP/NP_{-LEX,agr})/(S\backslash NP_{agr})$ must be added to the English lexicon for *know*. *Every boy* cannot combine with that because it is $+LEX$ical.

How Universals Invert Scope Out of NP Modifiers

- (19) a. Some apple in every barrel was rotten.
  b. Someone from every city despises it/#the dump

- Cf. the *wh*-island:

  (20) #A City that every person from admires sincerity.

- But also cf. Pied-Piping, Parasitic Gaps, and In-situ *wh*

  (21) a. A city Every person from which despises it
  b. A city that every person from despises
  c. Who despises every person from which city?

How Universals Invert Scope Out of NP Modifiers

(22)

Some apple in	every barrel	was rotten
$(S/(S\backslash NP))/NP : \lambda x\lambda p.p(skolem'\lambda y.apple'y \wedge in'x\,y)$	$NP^{\uparrow} : \lambda p.\forall x[barrel'x \rightarrow px]$	$S\backslash NP : rotten'$

$$S/(S\backslash NP) : \lambda p.\forall x[barrel'x \rightarrow p(skolem'\lambda y.apple'y \wedge in'x\,y)] \quad <$$

$$S : \forall x[barrel'x \rightarrow rotten'(skolem'\lambda y.apple'y \wedge in'x\,y)] \quad >$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$S : \forall x[barrel'x \rightarrow rotten'sk^{(x)}_{\lambda y.apple'y \wedge in'x\,y}]$$

- Pied-Piping, Parasitic Gaps, and In-situ *wh* can be analyzed the same way.

Inverse Scope Limits Readings

- This process only supports four distinct readings for the following:

(23) a. Some representative of every company saw every sample.
b. Every representative of some company saw every sample.

Inverse Scope Limits Readings

- The four readings are as follows:

(24) a. $\forall y[company'y \rightarrow saw'sk^{(y)}_{sample'}sk^{(y)}_{\lambda x.representative'x \wedge of'yx}]$

b. $\forall y[company'y \rightarrow saw'sk^{(y)}_{sample'}sk_{\lambda x.representative'x \wedge of'yx}]$

c. $\forall y[company'y \rightarrow saw'sk_{sample'}sk^{(y)}_{\lambda x.representative'x \wedge of'yx}]$

d. $\forall y[company'y \rightarrow saw'sk_{sample'}sk_{\lambda x.representative'x \wedge of'yx}]$

Why Non Universals Don't Invert Scope

- Non-universals cannot invert scope because they are not quantificational:

(25) a. Some linguist can program in at most two programming languages.
b. Most linguists speak at least three/many/exactly five/no/most languages.

- Hirschbühler (1982) pointed out that, exceptionally, they supported inversion out of VP ellipsis. Something else is going on there (see *TS*).

- Chierchia (1995) points out that apparent exceptions like "a Canadian flag was hanging in front of at least five windows," crucially involve unaccusatives, passives, etc.

Conclusion

- Most so-called quantifiers aren't generalized quantifiers. (Many languages appear to entirely lack true generalized quantifiers—Baker 1995; Bittner 1994; Aoun and Li 1993).

- The account combines the advantages of both DRT and E-type theories with a movement-free syntax and semantics.

- The analysis of donkey sentences in *TS* escapes the Scylla of the proportion problem and the Charybdis of the uniqueness problem, without the involvement of category ambiguity for existentials or minimal situations.

Conclusion (Contd.)

- Scope relations are defined lexically at the level of logical form, and projected onto the sentence by combinatory derivation The pure syntactic combinatorics of CCG is the source of all and only the grammatically available readings.

- All logical-form level constraints on scope-orderings can be dispensed with—a result related to, but more powerful than, that of Pereira 1990, as extended in Dalrymple et al. 1991, Shieber et al. 1996 and Dalrymple et al. 1997.

- Some but not all of these results transfer to other non-TG frameworks, such as LTAG, LFG, HPSG, and recent MP and DRT.

- However, the interactions of scope and coordinate structure discussed here seem to demand the specific syntactic combinatorics of CCG.

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