From Montague Semantics to MTT-semantics: A Meaningful Comparison

Lecture 3: Case Study on modification (given by SC)

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Overview

- Case study on modification
  - Aspects of both adjectival and adverbial modification
- Providing a standard/representative account in the Montagovian tradition along with an MTT one
  - Not meant to be exhaustive: MG approaches to modification are numerous
    - Our goal is not to compare against every conceivable MG account, but to provide comparisons that will highlight differences and similarities between the two systems

Modification: adjectival

- Traditional coarse grained classification of adjectives [Kamp(1975), Partee(2010)]
    - Intersective (e.g. *black*)
    - Subsective (e.g. *skillful*, *small*)
    - Non-subsective
        - Privative (e.g. *fake*)
        - Non-committal (e.g. *alleged*)

Modification: adjectival

- Classification based on basic inferential properties

Classification	Inference	Example	MTT-types/mechanisms
Intersective	Adj[N] $\Longrightarrow$ N & Adj	handsome man	Σ-types
Subsective	Adj[N] $\Longrightarrow$ N	large mouse	Π-polymorphism
Privative	Adj[N] $\Longrightarrow$ $\neg$N	fake gun	disjoint union types
Non-committal	Adj[N] $\Longrightarrow$?	alleged criminal	modal collection

Modification: adjectival

- Other types of adjectives we are going to be looking at
  - Gradable adjectives
  - Multidimensional adjectives

Intersective/Subsective/Non-subsective: the view from Montague Semantics

- Standard Montagovian approach: adjectives are higher-order properties
  - Type for adjectives: $(s \rightarrow (e \rightarrow t)) \rightarrow (s \rightarrow (e \rightarrow t))$ (intersectives are taken by some authors to be of type $s \rightarrow (e \rightarrow t)$)
  - Inferential properties are then captured by using meaning postulates
    - $\exists P : e \rightarrow t.\forall Q : e \rightarrow t.\forall x : e.ADJ'(Q)(x) \rightarrow P(x) \wedge Q(x)$
      for each intersective adjective
    - $\forall Q : e \rightarrow t.\forall x : e.ADJ'(Q)(x) \rightarrow Q(x)$
      for each subsective adjective
    - $\forall Q : e \rightarrow t.\forall x : e.ADJ'(Q)(x) \rightarrow \neg Q(x)$
      for each privative adjective
    - $\forall Q : e \rightarrow t.\forall x : .ADJ'(Q)(x) \rightarrow ?$
      for each non-committal adjective

Intersective/Subsective/Non-subsective: the view from Montague Semantics

- Issues to consider: relies on meaning postulates
  - Meaning postulate for intersective adjectives does not exactly work. Why is this so?
    - Well, the existentially quantified P property is basically the property of the adjective, e.g. for *black*, it has to be property *Black*
    - Very difficult to secure that this property will be the one that the adjective needs
  - This existential quantification is vacuous, e.g. there is always the truth predicate satisfying this existential

Intersective/Subsective/Non-subsective: the view from MTTs

- Adjectival modification as involving Σ types, in line with Ranta (1994)
  - Intersective adjectives as simple predicate types and subsective as polymorphic types over the CN universe:
    - $[\![black]\!] : Object \rightarrow Prop$
    - $[\![small]\!] : \Pi A{:}CN.(A \rightarrow Prop)$ (the A argument is implicit)
    - For *black man*, we have: $\Sigma m{:}\,[\![man]\!]\,.\,[\![black]\!](m) < [\![man]\!]$ (via π_1)
      $< \Sigma m{:}\,[\![human]\!]\,.\,[\![black]\!](m)$ (via subtyping propagation)
      $< [\![human]\!]$ (via π_1)
  - For *small man*:
    - $\Sigma m{:}\,[\![man]\!]\,.\,[\![small]\!]\,[\![man]\!](m) < [\![man]\!]$ (via π_1)
    - BUT NOT: $\Sigma m{:}\,[\![man]\!]\,.\,[\![small]\!]\,[\![man]\!](m) <$
      $\Sigma a{:}\,[\![animal]\!]\,.\,[\![small]\!]\,[\![man]\!](a)$
    - Many instances of small: $small([\![man]\!])$ is of type $[\![man]\!] \rightarrow Prop$, $small([\![animal]\!])$ is of type $[\![animal]\!] \rightarrow Prop$

Intersective/Subsective/Non-subsective: the view from MTTs

- Privative adjectives like *fake*
  - We follow Partee (2007) and argue that privative adjectives are actually subsective adjectives which operate on CNs with extended denotations
    - For exaple, the denotation of *fur* is expanded to include both *real* and *fake* furs:

      (1) I don't care whether that fur is fake fur or real fur.

      (2) I don't care whether that fur is fake or real.

    - $G = G_R + G_F$ with $inl(r){:}G_R$ and $inr(f){:}G_F$
    - define: $real_g(inl(r)) = True \quad and \quad real_g(inr(f)) = False$; $fake_g(inl(r)) = False \quad and \quad fake_g(inr(f)) = True$.

Intersective/Subsective/Non-subsective: the view from MTTs

- Use Π-polymorphism to give a generic typing for privative adjectives like *fake*
  - Note that this conforms to Partee's idea that privative adjectives are in fact subsective
    - When fake is instantiated for a specific common noun A, we obtain a specific meaning $fake(A)$ for that CN
      $fake,\ real\ :\ \Pi A : \mathrm{CN}.\ (A \rightarrow Prop)$
      $fake(G) = fake_g$

Intersective/Subsective/Non-subsective: the view from MTTs

- We can define the adjective modifications by means of Σ
  - $\mathit{fake\ gun} = \Sigma g : G.\ \mathit{fake}(G, g)$
  - $\mathit{real\ gun} = \Sigma g : G.\ \mathit{real}(G, g)$

Intersective/Subsective/Non-subsective: the view from MTTs

- Note: there are no inferences associated with non-committal adjectives in this categorization
  - But, we want to say something about adjectives like *alleged*
    - We will use *alleged* as our example
  - Consider the example *John is an alleged murderer*
    - Informally: someone alleged that John is a murderer
    - Treatment: use modal collections!

Intersective/Subsective/Non-subsective: the view from MTTs

- $\exists h : Human.\ H_{h,alleged}(IS_{Human}(Murderer, j))$
- For each non-committal adjective, we have a corresponding modal operator.
  - for alleged, $H_{h,alleged}(P)$ says that h alleges P
  - for any $h : Human$ and any non-committal adjective Adj, the modal operator $H_{h,Adj}$ is a predicate over propositions:

$$H_{h,Adj} : Prop \rightarrow Prop.$$

  - $H_{h,Adj}$ is a collection of propositions
    - $H_{h,alleged}$ is the collection of allegations made by h.

$alleged_B : \mathrm{CN} \rightarrow \mathrm{CN} = \lambda A : \mathrm{CN}.\ \Sigma x : B.\ \exists h : Human.\ H_{h,alleged}(IS_B(A, x))$

Intersective/Subsective/Non-subsective: the view from MTTs

- Inferential properties by means of typing (at least for intersectives, subsectives and privatives) vs meaning postulates
- No higher order types vs higher order types
- No intensional types vs intensional types (in the sense of Montague)
- Rich typing stuctures help (Σ and Π types, disjoint union types) help in giving semantics for adjectives

Gradable adjectives: Kennedy 2007

- Gradable adjectives involve a degree parameter that is context sensitive, e.g. *tall for a woman, tall for a man* etc.
- A prominent, representative analysis by [Kennedy(2007)] unfolds as follows:
  - The positive form of an adjective works as follows:
    - It is a higher order measure function, where measure function is a function from entities to degrees ($e \to d$)
    - The definition: $pos = \lambda F : e \to d.\lambda x : e.(F(x) \geq \mathbf{s}(F))$
    - **s** is a context sensitive function from measure functions to degrees
    - Composing comparison classes with adjectives via Heim's . combinator. Consider composing the comparison class basketball player, $BB : e \to t$ and $tall : e \to d$ to $BB(tall) : e \to d$. Normal functional application will not work here, thus the use of the "dot" combinator

- We concentrate here on the analysis sketched in [Chatzikyriakidis and Luo(2019a), Chatzikyriakidis and Luo(2019b)]
    - Crucial assumptions
        - Use of indexed types, common nouns are indexed with degree parameters
        - Use of type polymorphism to get the desired context-dependency

- Let us take *tall* as an example
  - We introduce the universe *Degree* of all degree types, where $Height, Width... : Degree$
- Arguments of gradable adjectives are not simple types, but rather types indexed by degree parameters
  - For example, *human* can be refined he family of types indexed by heights: $HHuman : Height \to Type$
    - $HHuman(n)$ is the type of humans of height n.
      ,
- Definition of a height function
  - $height : \Pi i : Height.\ HHuman(i) \to Height$
  - $height(i, h) = i$.

Gradable adjectives: MTT-semantics

- We need a polymorphic standard for *tall*
  - The value is dependent on the noun, the adjective, and sometimes even some other contextual information
    - These correspond to types, a predicates and a contexts (in type theory)
    - Polymorphism and type dependency in MTTs is used
  - For D : *Degree*, we introduce the indexed universe $\mathrm{CN}_G(D)$, a subuniverse of CN, consisting of the CNs with the indexed degree

- General rules for $\text{CN}_G(D)$,

$$\frac{D : \mathit{Degree}}{\text{CN}_G(D) : \mathit{Type}} \qquad \frac{D : \mathit{Degree} \quad A : \text{CN}_G(D)}{A : \text{CN}}$$

- The polymorphic standard, STND.
  - $\mathrm{STND} : \Pi D : \mathit{Degree}\ \Pi A : \text{CN}_G(D).\ \mathit{ADJ}(A) \to D$
    $\mathit{ADJ}(A)$ is the type of syntactic forms of adjectives whose semantic domain is A
- Definition of tall:
  - $\mathit{tall} : \Pi i : \mathit{Height}.\ \mathit{HHuman}(i) \to \mathit{Prop}$
  - $\mathit{tall}(i, h) = \mathit{height}(i, h) \geq \mathrm{STND}(\mathit{Height}, \mathit{Human}, \mathit{TALL})$

Gradable adjectives: Comparison

- The accounts achieve similar results. However:
  - Indexing on the noun by means of a degree gives one for free the fact that we are not talking about tallness in general but tallness with respect to the relevant class
    - No need for the "dot" combinator
  - The polymorphic STND function is, we believe, a more straightforward interpretation of Kennedy's context sensitive function from measure functions (adjectives basically) to degrees

Multidimensional adjectives

- Gradability across more than one domain
  - E.g. consider *healthy*: to be considered healthy, one has to be healthy across all "health dimensions" (or most of them)
    - Healthy is an example of a positive multidimensional adjective, where quantification is across all (or most) of its degrees
  - Consider its antonym, *sick*: to be considered sick, one dimension is enough
    - Sick is an example of a negative multidimensional adjective

Multidimensional adjectives

- The account by [Sassoon(2012)]: introduction of a higher order DIM predicate, taking predicates as arguments (healthy, sick)
- $Healthy = \lambda x.\forall Q \in DIM(healthy).healthy\text{-}wrt(x, Q)$
- $Sick = \lambda x.\exists Q \in DIM(healthy).healthy\text{-}wrt(x, Q)$

Multidimensional adjectives: MTTs

- Account put forth in [Chatzikyriakidis and Luo(2019b)]
  - Consider *healthy*.
  - We introduce the inductive (basically an enumerated type) *Health*
    - Inductive *Health* : D := Heart | Blood_ pressure | Cholesterol.
  - We then define:
    - $Healthy = \lambda x{:}Human.\forall h : Health.healthy(h)(x)$
    - $Sick = \lambda x{:}Human.\neg(\forall h : Health.healthy(h)(x))$

Multidimensional nouns

- A noun like *bird*, at least according to theories like Prototype and Exemplar theories is argued to involve a rich couple of dimensions
  - For something to count as a bird, a couple of different dimensions (for example, dimensions like *winged*, *small*, *can breed*, etc.) have to be taken into consideration
  - Conceptual structure of a noun like *bird* will involve an ideal value for each dimension.
  - Similarity measure is mapping entities to degrees, representing how far from the ideal dimensions of the prototype the values for the respective entities are (it is claimed that this is represented as a weighted sum)

Multidimensional nouns

- Dimensions integrate (another way of putting it is collapse) into a unique degree, thus not accessible for quantification as it is the case with multidimensional adjectives
- Viewing common nouns as types seems to be compatible with this.
- In order for an object to be of a CN type, the standard of membership w.r.t the weighted sum of its similarity degrees to the ideal values in the dimensions of the noun has to be exceeded.
- Between these two types of multidimensionality, i.e. multidimensional adjectives like *healthy* and multidimensional nouns like *bird*, we find social nouns like *linguist, artist*.
- Behave like multidimensional adjectives, with dimensions accessible:
  - He is an artist in many respects.

Multidimensional nouns: formalizing

- Types in these cases become more elaborate
  - Consider *artist*, and the inductive type for all its dimensions
    - Inductive $Art : D := a_1 \mid a_2 \mid a_3$
    - $artist = \Sigma h : Human.\forall a : Art.DIM_A(h, a) \times a \geq ...$ (we need a definition of a standard for multidimensional adjectives) with $DIM_{CN} : \Pi h : Human.\ \Pi a : Art.\ F(a)$ and $F : Art \rightarrow Nat$
    - Working on this!

Multidimensional adjectives

- MTT rich typing and typing structures allows one to introduce suitable structures for multidimensional adjectives
- The account seems to be fit to extend to cases of multidimensional nouns

Modification: adverbial

- Basic typings for adverbs
  - Montague Semantics
    - $(s \rightarrow (e \rightarrow t)) \rightarrow (s \rightarrow (e \rightarrow t))$
    - $t \rightarrow t$
  - MTT-semantics
    - $\Pi A : \mathrm{CN}.\ (A \rightarrow Prop) \rightarrow (A \rightarrow Prop)$
    - $Prop \rightarrow Prop$

- If a proposition A comprised of the adverb plus a proposition B (or the VP) is true, then the B is true as well
  - Fortunately, John opened the door $\Longrightarrow$ John opened the door
- A classic Montagovian analysis(e.g. [Montague(1970), Kamp(1975), Parsons(1972)] can of course do this by providing a meaning postulate

- Define $VER_{Prop}(v)$ (with $VER_{Prop} : Prop \rightarrow Prop$)
  - $VER_{Prop}(v) = \forall P : Prop.(P \rightarrow v)$
- With this we can prove:
  1. $fortunately(v) \rightarrow v$ (for $v : Prop$)
  2. $\forall P : Prop.\ (P \rightarrow v) \rightarrow fortunately(v)$

Modification: manner adverbs

- Classic treatments involve neo-davidsonian assumptions
- *slowly*: the event under consideration is a slow one.
  - However, it is the manner of the event rather than the event itself that is slow
    - Inclusion of manners in the semantic ontology [Dik(1975), Schäfer(2008)]
    - *John wrote illegibly* = $\exists e[subject(john, e) \wedge write(e) \wedge \exists m[manner(m, e) \wedge illegible(e)]]$

Modification: manner adverbs in MTTs

- We introduce the type *Event* : *Type*.
- We further introduce *Manner* : *Type*
  - Assume the family of types $Event : Manner \rightarrow Type$ indexed by manners
    - $Event_m$ (with $m : Manner$) is the type of events of manner m.
    - typing: $ADV_{manner} : \Pi m : Manner.\ \Pi A : \mathrm{CN}.\ (A \rightarrow Event_m \rightarrow Prop) \rightarrow (A \rightarrow Event_m \rightarrow Prop)$ (m and A are implicit)
  - Lexical entry for *illegibly*:
    - $illegibly = \lambda P : (Human \rightarrow Event_m \rightarrow Prop).\lambda x : Human.\lambda E : Event_m.P(x)(E) \wedge illeggible(m)$
      with $illegible : Manner \rightarrow Prop$

- MTT semantics can capture at least as much as the MG approaches
  - One might argue that the rich typing structures give a more principled way of talking about manners, events etc.
    - Within a Montagovian setting, based on Church's simple types, one has to do something extra to accommodate additional types like *Manner*

Adverb modification: Intensional Adverbs

- Epistemic adverbs create opaque contexts for both the subject and the object, while adverbs like *intentionally*, only for the object:
  - Oedipus allegedly married Jocaste.
  - Oedipus intentionally married Jocaste.
    - From the first, we obtain:
    1. Oedipus allegedly married Jocaste $\not\Rightarrow$ the son of Laius allegedly married Jocaste
    2. Oedipus allegedly married Jocaste $\not\Rightarrow$ Oedipus allegedly married his mother

    - From the second we obtain:
    1. Oedipus intentionally married Jocaste $\Rightarrow$ The son of Laius intentionally married Jocaste
    2. Oedipus intentionally married Jocaste $\not\Rightarrow$ Oedipus intentionally married his mother

Adverb modification: Intensional Adverbs

- Montague semantics: use possible worlds semantics, intensional typings for adverbs
  - Generalizing to the worst case: all adverbs, even non-intensional ones have intensional typings

Adverb modification: Intensional Adverbs

- We concentrate on *intentionallly* here
- [Chatzikyriakidis and Luo(2017)] propose that A intentionally P means that A has the intention P and furthermore fulfilled this intention, i.e. P holds
  - Introduction of intention contexts, which represent an agent's collection of intentions
    $\mathcal{D}_p = x_1 : A_1, ..., x_n : A_n(x_1, ..., x_{n-1})$
  - Use of a generalized intention operator I_p
    - $Intentionally = \lambda x : Human.\lambda P : Human \rightarrow Prop.\ I_x(P(x))$

Adverb modification: Intensional Adverbs

- Suffers from hyperintensionality!
  - Classical treatment of beliefs by [Ranta(1994)], which is used by [Chatzikyriakidis and Luo(2017)] is prone to hyperintensional problems
    - Beliefs are closed under derivability: if one believes P, s/he believes every proposition that is logically equivalent to P. This extends to intentional contexts as well
    - if $M(O, J)$ is part of Oedipus' intentional context, then one can derive that Oedipus intentionally married his mother given that $M(O, J) = M(O, MoO)$

- Solution: Modal collections
  - We introduce modal collections, representing agents' collections of beliefs, intentions etc.
    - $B_h : Prop \to Prop\ (B_h(P) ifP \in B_h\ )$
    - $I_h : Prop \to Prop\ (I_h(P) ifP \in I_h\ )$
    - $Intentionally = \lambda x : Human.\lambda P : Human \to Prop.\ I_x(P(x))$
    - If $B_h(P)$ and you can derive Q from P, you cannot derive $B_h(Q)$ if Q is not in B_h

- A nice test case for formal semantics: diverse and notoriously difficult
  - A further nice test to compare alternative theories of formal semantics
- MTTs vs Montague Semantics
  - Inferences via typing instead of meaning postulates
  - Rich typing structures provide a more natural habitat for more fine-grained phenomena, where more types are needed (e.g. manners, events)
  - Direct support of proof-theoretic reasoning
  - No need for intensional typing, let alone for cases it is not needed

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