Anaphora and Ambiguity in Narratives

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Exception Tolerance

- We want to phrase principles like this: *Statives don't like to be Results.*

- But statives aren't *forbidden* from being results.

(1) John shot Bill. ?He was dead. (✓He died.)

(2) I threw a giant water balloon at Hans. His shirt was wet.

Revision

(3) John took a train from Paris to Istanbul.
He has family there.

(4) John took a train from Paris to Istanbul.
He has family there and he wanted to get away from them.

Commonsense Entailment

We're going on a Tangent!

- We want to formalise the notion "typically" or "normally".
- This is so we can say "typically, a discourse with such and such linguistic form has such and such coherence form")
  - Construction of SDRSs from natural language discourses.
- We also want to say something like "speaker A thinks that normally salmon and cheese are a great dinner"
- We do this in default logics, logics that license statements like "X entails Y unless it doesn't"
- Because this is weird, I'm showing you one such logic.

Reasoning with Exceptions

- We feel entitled to use these sentences in inference.

(5) Birds fly.

Tux is a bird.

Tux flies.

- We feel that such inferences blocked without contradiction.

(6) Birds fly.

Tux is a bird.

Tux doesn’t fly.

~~Contradiction.~~

The Epistemic Argument (Pelletier & Asher 1997)

- Exception-tolerant statements form a large part of our knowledge.
  - And that knowledge is true, inferentially tractable, *good*.
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- Commonsense Knowledge.
- $\approx$ the knowledge of regularity while being simultaneously aware that regularities can be broken.

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- Commonsense Knowledge.

- $\approx$ the knowledge of regularity while being simultaneously aware that regularities can be broken.

- That is, we want:

(a) Truth-conditional semantics *for* commonsense knowledge.

(b) Inference *on* commonsense knowledge.

Default Logic

- Default Logics are logics of nonmonotonic inference.
  > Monotonicity: If $\Gamma \vdash \psi$ then $\Gamma, \varphi \vdash \psi$.

- The idea is that added information can cancel inferences.
  > "A entails B ($A \vdash B$) unless it happens to be the case that $\neg B$. Then A doesn't entail B ($A, \neg B \nvdash B$)

  > "A entails B unless we are in a state where it A came to be through **abnormal circumstances**, in which A doesn't entail B."

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  - "A entails B unless we are in a state where it A came to be through **abnormal circumstances**, in which A doesn't entail B."

- Goal: define an ceteris paribus-conditional $>$ and with a default entailment relation $\mid\!\sim$ (default inference).
- Defeasible Modus Ponens:
  $A, A > B \mid\!\sim B$.
  $A, A > B, \neg B \mid\!\not\sim B$.

Simple Transformations

(7) Birds fly.

Airplanes fly.

Things that are Birds or Airplanes fly.

- $b > f, a > f \mid\!\sim (b \vee a) > f$.
  (Disjunction of the Antecedent).

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Birds have wings.

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The Nixon Diamond

(9) Richard Nixon is a Quaker.
Richard Nixon is a Republican.
Republicans are warmongers.
Quakers are pacifists.

~~Nixon is a warmonger~~.
~~Nixon is a pacifist~~.

- When in doubt, conclude neither.

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- $q, r, r > w, q > p, \neg(w \wedge p) \not\mid\!\approx p$

- $q, r, r > w, q > p, \neg(w \wedge p) \not\mid\!\approx w$

Nixon Diamond: Result and Statives

- In the ULF language we'll want to say something like this:

$$R(\alpha, \beta) \wedge \mathit{stative}(\beta) > \neg(R = \mathit{Result})$$

$$R(\alpha, \beta) \wedge \Diamond\texttt{cause}(e_\alpha, e_\beta) > R = \mathit{Result}$$

(10) John shot Bill. ?He was dead.

$$R(\alpha, \beta) \wedge \mathit{eventive}(\alpha) \wedge \mathit{stative}(\beta) > R = \mathit{Background}_{\mathrm{bck}}$$

The Penguin Principle

(11) Birds fly.

Penguins don't fly.

Penguins are birds (by definition).

Tux is a penguin.

~~Tux flies.~~

Tux doesn't fly.

- The more specific inference wins.

- You can always be more specific.

(12) Birds fly.
Penguins don’t fly.
All Penguins are Birds.
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- You can always be more specific.

(12) Birds fly.
Penguins don't fly.
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Tux is a penguin.
Penguins with jetpacks fly.
Tux is a *jetpack* penguin

~~Tux doesn't fly.~~
Tux flies.

Penguin Principle: Narration and Explanation

- In the ULF language we'll want to say something like this:

$$R(\alpha, \beta) \wedge \textit{stative}(\alpha) \wedge \textit{eventive}(\beta) > R = \textit{Background}_{\text{fwd}}$$

$$R(\alpha, \beta) \wedge \textit{stative}(\alpha) \wedge \textit{eventive}(\beta) \wedge \Diamond \texttt{cause}(e_\beta, e_\alpha) > R = \textit{Expl}$$

(13) Bill was dead. John shot him.

Truth–Conditions for $>$ (kudos to Nicholas Asher)

- The idea is that $p > q$ is true if in all circumstances where p holds and these are normal circumstances for p, then q holds.

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- The idea is that $p > q$ is true if in all circumstances where p holds and these are normal circumstances for p, then q holds.
- We express this with the following modal semantics.

Commonsense Entailment Frames

A commonsense entailment frame is a tuple $\langle W, * \rangle$ where W is a set of worlds (propositional models) and $* : W \times \mathcal{P}(W) \to \mathcal{P}(W)$ is a function ("normality") such that:

- for all $w \in W$, $*(w, X) \subseteq X$,
- If $*(w, X) \subseteq Y$ and $*(w, Y) \subseteq X$, then $*(w, X) = *(w, Y)$.
- for all w, X, Y: $*(w, X \cup Y) \subseteq *(w, X) \cup *(w, Y)$.

Truth

A commonsense entailment model is a structure $\langle W, *, V\rangle$ such that $\langle W, *\rangle$ is a CE frame and $V : W \to \mathcal{P}(\mathrm{At})$ is a valuation.

- $M, w \Vdash p$ iff $p \in V(w)$ for atoms p.
- $M, w \Vdash \neg A$ iff $M, w \nVdash A$.
- $M, w \Vdash A \wedge B$ iff $M, w \Vdash A$ and $M, w \Vdash B$.
- $M, w \Vdash \Box A$ iff for all v, $M, v \Vdash A$.
- $M, w \Vdash A > B$ iff $*(w, [\![A]\!]) \subseteq [\![B]\!]$
  where: $[\![\varphi]\!] = \{w' \in W \mid M, w' \Vdash \varphi\}$.

- A proposition A roughly corresponds to a set of worlds $[\![A]\!]$.
- We interpret $*$ to select all the worlds where A is normal.
- So the truth–conditions of $A > B$ are circumscribed as "everywhere where A is normally true, B is true."

Monotonic Commonsense Entailment

Validity

$\Gamma \models A$ iff on all models M and for all $w \in W^M$:
if $M, w \Vdash \Gamma$ then $M, w \Vdash A$.

- Standard arguments (finite model property) show that this is decidable for finite Γ.

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Lemma: Disjunction of the Antecedent

$\models ((p > r) \wedge (q > r)) \rightarrow ((p \vee q) > r))$.

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Lemma: Disjunction of the Antecedent

$\models ((p > r) \wedge (q > r)) \to ((p \vee q) > r))$.
Proof: Suppose $M, w \Vdash (p > r) \wedge (q > r)$. Then:
$*(w, [\![p \vee q]\!]) = *(w, [\![p]\!] \cup [\![q]\!]) \subseteq *(w, [\![p]\!]) \cup *(w, [\![q]\!]) \subseteq [\![r]\!]$. $\square$

Closure in the Consequent

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- Proof:
  - Fix a model M and a world w.
  - Assume $M, w \Vdash \Box(B \to C) \wedge (A > B)$.
  - By the first conjunct, $[\![B]\!] \subseteq [\![C]\!]$.
  - By the second conjunct, $*(w, [\![A]\!]) \subseteq [\![B]\!]$.
  - Hence $*(w, [\![A]\!]) \subseteq [\![C]\!]$.

Towards Defeasible Modus Ponens

- We now have a truth definition and a monotonic entailment relation that tells us from facts about generic statements further true generic statements.
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- So we know that if "Birds fly" and "Fliers have wings" that "Birds have wings",
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- We need a definition of $\mid\!\sim$ that valildates $A, A > B \mid\!\sim B$ and $A, A > B, \neg B \not\mid\!\sim B$.
- We are inclined to just take all normal worlds and check what is going on there.
  - However, this needs to be recursed. This is bonkers complicated.

Towards $\mid\!\sim$ (kudos to Alex Lascarides)

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- Let Γ be a finite set of formulae. Define:

$$\mathrm{Ant}(\Gamma) = \{A \mid \Gamma \models A > B \text{ for some } B\}.$$

For any $A \in \mathrm{Ant}(\Gamma)$ define:

$$\Gamma^A = \{(A > B) \rightarrow (A \rightarrow B) \mid \Gamma \models A > B\}.$$

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- An extension of Γ is an immediate extension of Γ or an immediate extension of an extension of Γ.

Commonsense Entailment (finally)

Propositional Commonsense Entailment

$\Gamma \mid\!\sim A$ iff $\Gamma^{\rightarrow} \models A$ for all maximally satisfiable extensions $\Gamma^{\rightarrow}$ of Γ.

- Recall that $\models$ is decidable; thus $\Gamma \mid\!\sim A$ is decidable.

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Propositional Commonsense Entailment

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- Recall that $\models$ is decidable; thus $\Gamma \mathrel{|\!\sim} A$ is decidable.
- It is easy to see that Defeasible Modus Ponens holds:
  - $A, A > B \mathrel{|\!\sim} B$ and $A, A > B, \neg B \mathrel{|\!\not\sim} B$.
  - But $A, A > B, C \mathrel{|\!\sim} B$ if C is not a defeater for B.
  - Because without a defeater, $(A > B) \rightarrow (A \rightarrow B)$ is in every consistent extension.

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- It is easy to see that Defeasible Modus Ponens holds:
  - $A, A > B \mathrel{|\!\!\sim} B$ and $A, A > B, \neg B \not\mathrel{|\!\!\sim} B$.
  - But $A, A > B, C \mathrel{|\!\!\sim} B$ if C is not a defeater for B.
  - Because without a defeater, $(A > B) \rightarrow (A \rightarrow B)$ is in every consistent extension.
- Nixon Diamond:
  - $A > B, C > \neg B, C, A \not\mathrel{|\!\!\sim} B$.
  - $A > B, C > \neg B, C, A \not\mathrel{|\!\!\sim} \neg B$.
  - Because there are consistent extensions with B and with $\neg B$.

Specificity (kudos to Michael Morreau)

- We need one more lemma for the penguin principle:
- $\models \big(\Box(P \to B) \land (B > F) \land (P > \neg F)\big) \to (B > \neg P)$.
  (Penguins are birds, birds fly, penguins do not fly.
  Thus, normal birds are not penguins.)

Specificity (kudos to Michael Morreau)

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  (Penguins are birds, birds fly, penguins do not fly.
  Thus, normal birds are not penguins.)
- Proof:
  - Fix a model M and a world w. Assume the antecedent of the conditional.
  - Then $[\![P]\!] \subseteq [\![B]\!]$, i.e. $[\![B]\!] = ([\![B]\!] \setminus [\![P]\!]) \cup [\![P]\!]$.
  - Then $*(w, [\![B]\!]) \subseteq *(w, [\![B]\!] \setminus [\![P]\!]) \cup *(w, [\![P]\!])$.
  - Also $*(w, [\![P]\!]) \subseteq [\![\neg F]\!]$ and $*(w, [\![B]\!]) \subseteq [\![F]\!]$.
  - So $*(w, [\![P]\!])$ and $*(w, [\![B]\!])$ are disjoint.
  - Thus $*(w, [\![B]\!]) \subseteq *(w, [\![B]\!] \setminus [\![P]\!])$.
  - Hence $*(w, [\![B]\!]) \subseteq [\![B]\!] \setminus [\![P]\!] \subseteq [\![\neg P]\!]$. $\square$

The Penguin Principle

- To show: $\Box(P \rightarrow B), B > F, P > \neg F, P \mid\!\sim \neg F$.

  (Penguins are Birds; Birds fly; Penguins don't fly; we have a penguin $\mid\!\sim$ it doesn't fly)

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- Proof.
  - Let $\Gamma = \{\Box(P \to B), B > F, P > \neg F, P\}$.
    Then, $\mathrm{Ant}(\Gamma) = \{A \mid \Gamma \models A > X \text{ for some } X\} = \{P, B\}$.
  - We know: $\models \big(\Box(P \to B) \wedge (B > F) \wedge (P > \neg F)\big) \to (B > \neg P)$.
  - So $\Gamma \models B > \neg P$.
  - So it is inconsistent to extend Γ with the antecedent B:
    $\Gamma \cup \{(B > \varphi) \to (B \to \varphi) \mid \Gamma \models B > \varphi\} \models P \wedge \neg P$.
  - Thus B as an antecedent is defeated. All maximally consistent extensions of Γ contain $P \to \neg F$.
  - So we get $\Gamma \mathrel{|\!\sim} \neg F$. $\Box$

Underspecification, Resolution, Revision

Underspecified Logical Form

- The idea is this: we construct a language for incomplete descriptions of SDRSs.
- So we need a language for “underspecified logical form” (ULF).
- We need a formal statement for “this SDRS is described by this ULF”.

ULF Language: atoms and variables

- So what are the bits and pieces of an SDRS?
- DRSs
  - > Any DRS K is an "atom" (or, constant symbol).
    (you can underspecify these too, but I won't)
- Labels
  - > Take variable symbols for labels $l_1, l_2, \ldots$
- Coherence relations
  - > Take a constant symbol D_R for each coherence relation R
  - > Plus corresponding variable symbols $D_1, D_2, \ldots$

ULF Language: Structure

- We underspecify:
- What the contents are.
- Which contents are connected.
- How they are connected.

- Take two predicate symbols to describe assignment:
  - > $labels(l, K)$
  - > $relates(l_1, l_2, l_3, D)$

- And three to describe structure:
  - > $outscopes(l_1, l_2)$
  - > $accessible(l_1, l_2)$
  - > $last(l_1)$

ULF Language: Anaphor

- Anaphora are a type of underspecification.
- So take a constant symbol v_x for each DRT-variable x (do this for every type of variable).
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  - $anaphor(l, v)$

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- And add a predicate symbol:
  > $anaphor(l, v)$
- (If you extend the language to partially describe microstructure, you can write anaphora as $x =?$ to indicate something like “x is not in the universe of K”.)

Examples

- ULFs are constructed from surface form.

(14) There is a woman.

$$labels(l_1, \boxed{\begin{array}{l} \text{x} \\ \hline \texttt{woman}(\text{x}) \end{array}})$$

(15) She runs.

$$labels(l_2, \boxed{\begin{array}{l} \text{e,y} \\ \hline \texttt{run}(\text{e}) \\ \texttt{actor}(\text{e,y}) \end{array}}) \wedge anaphor(l_2, v_y)$$

Two Sentence Example

(16) There is a woman. She runs.

$$
\begin{aligned}
& labels(l_1, \boxed{\begin{array}{l} \text{x} \\ \hline \mathtt{woman}(\text{x}) \end{array}}) \\
\wedge\ & labels(l_2, \boxed{\begin{array}{l} \text{e,y} \\ \hline \mathtt{run}(\text{e}) \\ \mathtt{actor}(\text{e,y}) \end{array}}) \wedge anaphor(l_2, v_y) \\
\wedge\ & relates(l_0, l_1, l_2, D) \\
\wedge\ & last(l_2)
\end{aligned}
$$

ULF Language: Cue Phrases

- Add an (empirically sourced) vocabulary of linguistic cues to this language.

- therefore $\rightsquigarrow$ *therefore*(*l*)
- and then $\rightsquigarrow$ *and-then*(*l*)
- I hereby command $\rightsquigarrow$ *command*(*l*)
- I hereby assert $\rightsquigarrow$ *inform*(*l*)

- Including grammatical features:

- *declarative*(*l*)
- *interrogative*(*l*)
- *imperative*(*l*)

Plus tense, aspect, mood ... – **anything useful from the grammar!**

From ULF to SDRS

- The underspecified language has the formulas we seen so far, closed under the logical constants $=$, $\neg$, $\vee$ and $\wedge$.
  - > **This logic has no quantifiers. All variables are implicitly existentially closed.**

- Call a formulae in this language an ULF (underspecified logical form).

From ULF to SDRS

- The underspecified language has the formulas we seen so far, closed under the logical constants $=$, $\neg$, $\vee$ and $\wedge$.
  - **This logic has no quantifiers. All variables are implicitly existentially closed.**

- Call a formulae in this language an ULF (underspecified logical form).

- Now, this is conceptually a bit weird, but not hard:

- We want to define a turnstile $\models$ such that for an SDRS S and an ULF $\mathcal{K}$, $S \models \mathcal{K}$ iff all descriptions from $\mathcal{K}$ are realised in S.

Assignment Function

- Let $S = (\Pi, \mathcal{F}, L)$ be an SDRS and A be a function s.t.:
  - for each variable l_i, $A(l_i) \in \Pi$
  - for each variable D_i, $A(D_i)$ is some coherence relation.
  - $A(D_R) = R$ for all coherence relations R
  - $A(v_x) = x$ for all and DRT-variables x.

- (i.e. the variables are implicitly existentially quantified)

- $S, A \models x = y$ iff $A(x) = A(y)$ (for any variables or constants x, y)

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- $S, A \models \mathit{relates}(l_1, l_2, l_3, D)$ iff $A(D)(A(l_2), A(l_3))$ is a conjunct of $\mathcal{F}(A(l_1))$.

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- $S, A \models \mathit{outscopes}(l_1, l_2)$ iff $A(l_2)$ outscopes (in S) $A(l_1)$.

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- $S, A \models accessible(l_1, l_2)$ iff $A(l_1)$ is accessible (in S) from $A(l_2)$.
  - This is the right frontier. See Wednesday slides.

- $S, A \models x = y$ iff $A(x) = A(y)$ (for any variables or constants x, y)
- $S, A \models \mathit{last}(l_1)$ iff $A(l_1) = L$.
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  iii. $\mathcal{F}(A(l))$ has a condition $A(v) = z$.

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  ii. λ is accessible to β; and
  iii. $\mathcal{F}(A(l))$ has a condition $A(v) = z$.
- If $\mathit{cue}(l)$ is a linguistic cue predicate, $S, A \models \mathit{cue}(l)$ always.

Important!

The ULF language has no world model. It is not about the world, it is only about the construction of SDRSs.

Linguistic Form to Coherence Structure

- So, given the linguistic form of a discourse, we:
  - Compute for every *clause* the corresponding DRS K (by the DRT construction algo), except that we don't resolve anaphora here.
  - Pick an unused label variable l_1 and add $labels(l_1, K)$.
  - (If there is an ambiguity, you can also add $labels(l_1, K) \vee labels(l_1, K')$).
  - For every anaphor x in K add $anaphor(l_1, v_x)$.
  - Add appropriate predicates on l for cue phrases and linguistic features (aspect etc.).
  - For every clause except the very first one, pick another two unused label variables l_0, l_2 and add $relates(l_0, l_2, l_1, D)$ (i.e. l_1 attaches somewhere)
- Call the conjunction of all these $\mathcal{K}$.

Two Sentence Example

(17) Phil tickled Stanley. He laughed.

$$
\begin{array}{ll}
 & \mathit{labels}(l_1, \boxed{\begin{array}{l} p, s, e_1 \\ \hline \mathtt{tickling}(e_1) \\ \mathtt{actor}(e_1, p) \\ \mathtt{object}(e, s) \end{array}}\ ) \\
\wedge & \mathit{labels}(l_2, \boxed{\begin{array}{l} e_2, y \\ \hline \mathtt{laughing}(e_2) \\ \mathtt{actor}(e_2, y) \end{array}}\ ) \\
\wedge & \mathit{anaphor}(l_2, v_y) \\
\wedge & \mathit{relates}(l_0, l_1, l_2, D) \\
\wedge & \mathit{last}(l_2)
\end{array}
$$

(17) Phil tickled Stanley. He laughed.

$$A(l_0) = \pi_0, A(l_1) = \pi_1$$
$$A(l_2) = \pi_2, A(D) = Result$$
$$\Pi = \{\pi_0, \pi_1, \pi_2\}, L = \pi_2$$
$$\mathcal{F}(\pi_1) = \boxed{\begin{array}{l} p, s, e_1 \\ \hline \texttt{tickling}(e) \\ \texttt{actor}(e_1, p) \\ \texttt{object}(e, s) \end{array}}$$
$$\mathcal{F}(\pi_2) = \boxed{\begin{array}{l} e_2, y \\ \hline \texttt{laughing}(e_2) \\ \texttt{actor}(e_2, x) \\ y = s \end{array}}$$
$$\mathcal{F}(\pi_0) = Result(\pi_1, \pi_2)$$

$$\models \quad labels(l_1, \boxed{\begin{array}{l} p, s, e_1 \\ \hline \texttt{tickling}(e_1) \\ \texttt{actor}(e_1, p) \\ \texttt{object}(e, s) \end{array}})$$
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$$\wedge \quad last(l_2)$$

Two Sentence Example

(17) Phil tickled Stanley. He laughed.

$A(l_0) = \pi_0, A(l_1) = \pi_1$
$A(l_2) = \pi_2, A(D) = Correction$

$\Pi = \{\pi_0, \pi_1, \pi_2\}, L = \pi_2$

$$\mathcal{F}(\pi_1) = \boxed{\begin{array}{l} p, s, e_1 \\ \hline \texttt{tickling}(e) \\ \texttt{actor}(e_1, p) \\ \texttt{object}(e, s) \end{array}}$$

$$\mathcal{F}(\pi_2) = \boxed{\begin{array}{l} e_2, y \\ \hline \texttt{laughing}(e_2) \\ \texttt{actor}(e_2, x) \\ y = p \end{array}}$$

$$\mathcal{F}(\pi_0) = Correction(\pi_1, \pi_2)$$

$$\models$$

$$labels(l_1, \boxed{\begin{array}{l} p, s, e_1 \\ \hline \texttt{tickling}(e_1) \\ \texttt{actor}(e_1, p) \\ \texttt{object}(e, s) \end{array}})$$

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$$\wedge \quad anaphor(l_2, v_y)$$

$$\wedge \quad relates(l_0, l_1, l_2, D)$$

$$\wedge \quad last(l_2)$$

Enrichment

- The underspecified information that we get *directly* from the linguistic form needs to be *enriched* with more information.
  - > Pragmatic, world knowledge, cue phrases need to be interpreted...
- So we use Commonsense Entailment again to phrase a *logic for enrichment of ULFs*.
- It's called the Glue Logic (GL).

Glue Language

- The Glue Language is obtained from the underspecified language by adding the connectives $\rightarrow$ and $>$.
  - still no quantifiers
- Moreover, the Glue Language contains additional predicates for world knowledge
  - $\mathtt{cause}(e_1, e_2)$ for "e_1 causes e_2".
- Commonsense entailment really only works on decidable logics.
- DRT-Entailment is not decidable, so we still only use *K*'s as *tokens*—we only know them by their description, but have no *truth-conditional* knowledge of their *meaning* in this logic.
  - '$\mathtt{cause}(e_1, e_2)$' is a single propositional atom. We could (maybe should) write it as $p_{\mathtt{cause}(e_1, e_2)}$.

Enrichment by Axioms

- In the Glue language, we *hard-code* “rational assumptions” about how discourses are typically interpreted.
- A script for occasion is a Glue formula to infer occasion from content-level information (i.e. from descriptions of DRSs):

Enrichment by Axioms

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- A script for occasion is a Glue formula to infer occasion from content-level information (i.e. from descriptions of DRSs):
- One suggested by Asher & Lascarides:

$$\begin{aligned} & \mathit{relates}(l_0, l_1, l_2, D) \\ \wedge\ & \mathit{labels}(l_1, K_1) \wedge \mathtt{fall}(e_1, x_1) \in K_1 \\ \wedge\ & \mathit{labels}(l_2, K_2) \wedge \mathtt{help\text{-}up}(e_2, x_2, x_3) \in K_2 \\ >\ & \mathit{occasion}(e_1, e_2) \end{aligned}$$

- $\mathit{relates}(l_0, l_1, l_2, D) \wedge \mathit{occasion}(l_1, l_2) > \mathrm{Narration}(l_1, l_2)$
- (I use italics for Glue predicates and monospace for tokenised DRT predicates; AL2003 use brackets, e.g. [*fall*])

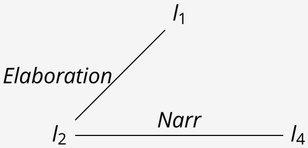
This Seems Very Tedious

- The Big Problem of Formal Pragmatics: how do these things generalise?
- At the current state of research, we can describe mechanisms for pragmatic inference.
- But we need to hard code world knowledge, lexical knowledge etc.
- Part of our mechanisms is also a language for hard-coding.

“Structural” Principles (Asher 1993)

- We also encode certain stipulation about what is a “good” story.
- For example, that sub-stories form complex segments.

$$
\begin{aligned}
&\big(\mathit{relates}(l_0, l_1, l_2, D_1)\\
&\wedge \mathit{relates}(l_3, l_2, l_4, D_2)\\
&\wedge D_1 = \mathit{Elaboration}\\
&\wedge \mathit{Coordinating}(D_2)\big)\\
\rightarrow &\big(\mathit{outscopes}(l_5, l_2) \wedge \mathit{outscopes}(l_5, l_4)\\
&\wedge \mathit{relates}(l_0, l_1, l_5, D_{Elab})\big)
\end{aligned}
$$



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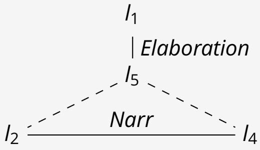

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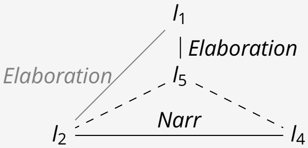

Inferring Relations: sufficiency

- SDRT typically includes Glue axioms that state if all semantic consequences of a relation obtain (and this is known to the Glue logic), then the relation is inferred.
- ("the totality of necessary consequences is typically sufficient")
- $\mathit{labels}(l_1, K_1) \wedge \mathit{labels}(l_2, K_2) \wedge \mathit{relates}(l_0, l_1, l_2, R) \wedge \mathtt{cause}(e_2, e_1) > R = D_{\mathit{Explanation}}$.
- $\mathit{labels}(l_1, K_1) \wedge \mathit{labels}(l_2, K_2) \wedge \mathit{relates}(l_0, l_1, l_2, R) \wedge \mathtt{cause}(e_1, e_2) > R = D_{\mathit{Result}}$.

Notation

- Hereinafter, I will make our lives a bit easier, where possible:
  - > $R(\alpha, \beta) \wedge \texttt{cause}(\beta, \alpha) > R = \mathit{Explanation}$.
- Typical abbreviation in SDRT papers:
  - > $\lambda :?(\alpha, \beta) \wedge \texttt{cause}(K_\beta, K_\alpha) > \lambda : \mathit{Explanation}(\alpha, \beta)$.

Explanatoriness?

- You don't have to do *everything* by piecemeal.

$\Box(R(\alpha,\beta) \land subord(R) \rightarrow (R'(\alpha,\beta) \rightarrow \neg coord(R')))$

Explanatoriness?

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$$\Box(R(\alpha,\beta) \wedge subord(R) \rightarrow (R'(\alpha,\beta) \rightarrow \neg coord(R')))$$

$$R(\alpha,\beta) \wedge eventive(\alpha) \wedge stative(\beta) > R = Background_{\mathrm{bck}}$$
$$R(\alpha,\beta) \wedge stative(\alpha) \wedge eventive(\beta) > R = Background_{\mathrm{fwd}}$$
$$R(\alpha,\beta) \wedge stative(\alpha) \wedge stative(\beta) > R = BG_{\mathrm{fwd}} \vee R = BG_{\mathrm{bck}}$$

- You get this for free:

$$R(\alpha,\beta) \wedge stative(\beta) > \neg(R = Result)$$

- But not this:

$$R(\alpha,\beta) \wedge stative(\alpha) > \neg(R = Explanation)$$

Inferring Relations: Cue Phrases

- Monotonic cues:
  $(R(\alpha, \beta) \wedge \mathit{therefore}(\beta)) \rightarrow R = \mathit{Result}$
  $(R(\alpha, \beta) \wedge \mathit{and\text{-}then}(\beta)) \rightarrow R = \mathit{Narration}$

- Performatives:
  $\mathit{assertoric}(\pi) \rightarrow$
  $((R(\lambda, \pi) \wedge \mathit{right\text{-}veridical}(R)) \vee (R(\pi, \lambda) \wedge \mathit{left\text{-}verdicial}(R)))$.

- Defeasible cues:
  $\mathit{declarative}(\pi) > \mathit{assertoric}(\pi)$
  $(R(\alpha, \beta) \wedge \mathit{and}(\beta)) > \mathit{coord}(R)$

Inferring Relations: Rationality Principles

- It is rational to interpret a response to a question as an answer:

$(R(\alpha,\beta) \wedge \textit{interrogative}(\alpha) \wedge \textit{declarative}(\beta) \wedge$
$\textit{spk}(\alpha) \neq \textit{spk}(\beta)) > R = \textit{Indirect Question Answer Pair}$

(18) a. A: Is John going out tonight?
b. B: I saw him dress up earlier.
IQAP

(19) a. A: Why is seaweed good for you?
b. B: Lots of vitamins.
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b. B: Lots of vitamins.
} IQAP

- A question after a declarative should ask something about it:

$(R(\alpha,\beta) \wedge \mathit{declarative}(\alpha) \wedge \mathit{interrogative}(\beta) \wedge$
$\mathit{spk}(\alpha) \neq \mathit{spk}(\beta)) > R = \mathit{Elaborating\text{-}Question}$

Back-flow of semantic information

- The following are Glue logic axioms:

$$(\mathit{relates}(l_0, l_1, l_2, D_{\mathit{Explanation}}) \wedge \mathit{labels}(l_1, K_1) \wedge \mathit{labels}(l_2, K_2))$$
$$\rightarrow \neg \mathit{before}(l_1, l_2) \wedge \texttt{cause}(e_2, e_1).$$

$$(\mathit{relates}(l_0, l_1, l_2, D_{\mathit{Narration}}) \rightarrow \mathit{before}(l_1, l_2) \wedge \mathit{occasion}(l_1, l_2).$$

- So if we already have inferred a relation, we learn a bit more about the label contents.
  - This is in spite of us not having proper access to these contents.

- We do this by encoding *our* knowledge about meaning postulates in such Glue axioms.
  - Have to do this because the Glue logic does *not* know the postulates.

SDRT-Update

Interpretation Schema

Linguistic Forms

are interpreted to

Glue Axioms

enrich⇒
⇐*include*

ULFs (partially describe content)

(stipulations about interpretation)

are specified to

SDRSs (describe coherence structure)

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Models

Construction of SDRSs (overview)

- Context (the information contained in the prior discourse) may contain underspecified / defeasible information.

- Thus, the context is a big ULF formula Γ (possibly empty).
  - If you so desire, let the context be set σ of SDRSs. Then define Γ to be the ULF that describes them all ($\Gamma = \mathit{Th}(\sigma)$, in the book).

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  - > If you so desire, let the context be set σ of SDRSs. Then define Γ to be the ULF that describes them all ($\Gamma = Th(\sigma)$, in the book).
- Now, let $\mathcal{K}$ a ULF representing new information. Let l_{new} be a label variable not not used in Γ. Then define:
- $update(\Gamma, l_{new} : \mathcal{K})$ is the set of all (and only) those pairs (S, A) (S an SDRS; A an assignment) where $L = A(l_{new})$ and that satisfy the defeasible consequences of attaching $\mathcal{K}$ to some available segment in Γ.

Construction of Discourse (formal)

- Let l_{new} be a label variable not used in Γ.
- Let R_n, l_1 and l_2 be variables not used in Γ.
- Let l_λ be the "last" label in Γ (i.e. the l_{new} from the last update).
  - Can also define this as the "accessibility-minimal" label.

- Then: $(S, A) \in update(\Gamma, l_{new} : \mathcal{K})$ iff $S = (\Pi, \mathcal{F}, L)$, is an interpretable SDRS with $L = A(l_{new})$, and for all formulae φ of the underspecified language (if $\Gamma \neq \emptyset$):

  If $\Gamma \wedge \mathcal{K} \wedge relates(l_1, l_2, l_{new}, R_n) \wedge accessible(l_2, l_\lambda) \mid\!\sim \varphi$, then $S, A \models \varphi$.

  (if $\Gamma = \emptyset$): If $\mathcal{K} \mid\!\sim \varphi$, then $S, A \models \varphi$.

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  If $\Gamma \wedge \mathcal{K} \wedge \mathit{relates}(l_1, l_2, l_{new}, R_n) \wedge \mathit{accessible}(l_2, l_\lambda) \mathrel{|\!\!\sim} \varphi$, then $S, A \models \varphi$.

  (if $\Gamma = \emptyset$): If $\mathcal{K} \mathrel{|\!\!\sim} \varphi$, then $S, A \models \varphi$.

good enough?

Some Remarks, to be clear

- We do not expect to arrive at *one* fully specified SDRS.
- A context will almost-always contain a certain amount of underspecification.
  - When we assign a single SDRS to a discourse we are to some degree using our magic human powers of interpretation.
- In addition, even if we get a single SDRS, the next utterance might require us to revise.
- So, *officially*, we consider a context to be the ULF that represents *only* the linguistic information of a linguistic form.
- We compute all the Glue-consequences anew *every time*.

Maximise Discourse Coherence

- There may be a *lot* of SDRSs in *update*$(\Gamma, \pi : \mathcal{K})$.
- We want to pick out the “best” ones.
- Intuitively, some ways of structuring a discourse “tell a better story” than others.
- We’ll call the good ones “most coherent” and formalise conditions on what such coherence might be.

MDC

An SDRS K is at least as coherent as an SDRS K', $K' \leq^c K$, if and only if all of the following hold:

1. *Prefer consistency:* If K' is consistent, then so is K.
2. *Prefer rich structure:* K has at least as many coherence relations as K'.
3. *Prefer resolution:* K binds (over accommodates) at least as many presuppositions as K' does.
4. *Prefer better relations:* For every rhetorical relation $R(\pi_1, \pi_2)$ that K' and K share: $R(\pi_1, \pi_2)$ is at least as coherent in K as it is in K'.
5. *Prefer flat structure:* K has at most as many labels as K' unless K' has a *semantic clash* and K does not.

(these are “global” conditions and cannot be put as glue axioms)

MDC: Clashes

- A semantic clash is a conflict of veridicality.

(20) a. π_1: If a shepherd goes to the mountains,
π_2: he will bring his dog.
π_3: He brings a good walking stick too.

✓b. π_0: $\mathit{Consequence}(\pi_1, \pi)$
π : $\mathit{Parallel}(\pi_2, \pi_3)$

✗c. π_0: $\mathit{Consequence}(\pi_1, \pi_2) \wedge \mathit{Parallel}(\pi_2, \pi_3)$

MDC: Quality of Relations

- Topic (Continuation & Narration) is scalar:

(21) a. Düsseldorf is the birth place of Heinrich Heine.
? Düsseldorf has a university.
b. Düsseldorf is the birth place of Heinrich Heine.
Its university is named after him.

- Contrast is scalar:

(22) a. John loves opera, but hates musicals.
?b. John loves opera, but likes musicals.

(23) a. John had pocket aces, but lost.
?b. John had a pair, but lost.

MDC: Quality of Relations, Example

- Sometimes the “better relation” decides some underspecified element.

(24) I thought Arshak was on the river. He was at the bank.

MDC: Quality of Relations, Example

- Sometimes the “better relation” decides some underspecified element.

(24) I thought Arshak was on the river. He was at the bank.

(25) I thought Arshak was on the river and he was at the bank.

(26) I thought Arshak was on the river, but he was at the bank.

A Framework, not an Answer to Everything

- Clearly, I have not given you a (even nearly) complete set of construction principles.

(27) I gave Arpine a dozen roses. She was thrilled.

- We have a preference to interpret possible causes to Result.
- But this preference is overridden by statives usually not being Results.
- Another preference, that eventive–stative constructions are usually Background "wins" here.
- What kind of Glue axiom would "defeat" that preference?

Full SDRT Interpretation

Linguistic Forms

are interpreted to

Glue Axioms (axioms for interpretation) *enrich*$\Rightarrow$ $\Leftarrow$*include* ULFs (partially describe content)

are specified to

MDC (axioms for rich structures) *selects* SDRSs (describe coherence structure)

are converted to

DRSs (describe event structure)

are evaluated in

Models

What we got

- We have a good theory of what discourse structure is, how it is evaluated, and how it is constructed.

- It is still open what the coherence relations are, what exactly they mean, and how exactly they are inferred.

DONE!

... but still so much to do.