NLP
Introduction to NLP

Inference
Modus Ponens

• Modus ponens:
  \[ \begin{align*}
  &\alpha \\
  &\alpha \implies \beta \\
  \hline
  &\beta
  \end{align*} \]

• Example:
  \[ \begin{align*}
  & Cat(Martin) \\
  & \forall x: Cat(x) \implies EatsFish(x) \\
  & EatsFish(Martin)
  \end{align*} \]
Inference

• **Forward chaining**
  – as individual facts are added to the database, all derived inferences are generated

• **Backward chaining**
  – starts from queries
  – Example: the Prolog programming language

• **Prolog example**
  – father(X, Y) :- parent(X, Y), male(X).
  – parent(john, bill).
  – parent(jane, bill).
  – female(jane).
  – male (john).
  – ?– father(M, bill).
The Kinship Domain

• Brothers are siblings
  \( \forall x,y \ Brother(x,y) \Rightarrow Sibling(x,y) \)

• One's mother is one's female parent
  \( \forall m,c \ Mother(c) = m \iff (Female(m) \land Parent(m,c)) \)

• “Sibling” is symmetric
  \( \forall x,y \ Sibling(x,y) \iff Sibling(y,x) \)
Universal Instantiation

• Every instantiation of a universally quantified sentence is entailed by it:

\[
\forall \nu \alpha \\
\text{Subst}\{\nu/g\}, \alpha
\]

for any variable \( \nu \) and ground term \( g \)

• E.g., \( \forall x \text{Cat}(x) \land \text{Fish}(y) \Rightarrow \text{Eats}(x,y) \) yields:

\( \text{Cat}(Martin) \land \text{Fish}(Blub) \Rightarrow \text{Eats}(Martin,Blub) \)
Existential Instantiation

- For any sentence $\alpha$, variable $v$, and constant symbol $k$ that does not appear elsewhere in the knowledge base:
  \[
  \exists v \alpha \\
  \text{Subst}\{\{v/k\}, \alpha\}
  \]

- E.g., $\exists x \text{Cat}(x) \land \text{EatsFish}(x)$ yields:
  
  \[
  \text{Cat}(C_1) \land \text{EatsFish}(C_1)
  \]

  provided $C_1$ is a new constant symbol, called a Skolem constant
Unification

• If a substitution $\theta$ is available, unification is possible

• Examples:
  – $p=\text{Eats}(x,y)$, $q=\text{Eats}(x,\text{Blub})$, possible if $\theta = \{y/\text{Blub}\}$
  – $p=\text{Eats}(\text{Martin},y)$, $q=\text{Eats}(x,\text{Blub})$, possible if $\theta = \{x/\text{Martin}, y/\text{Blub}\}$
  – $p=\text{Eats}(\text{Martin},y)$, $q=\text{Eats}(y,\text{Blub})$, fails because Martin $\neq$ Blub

• Subsumption
  – Unification works not only when two things are the same but also when one of them subsumes the other one
  – Example: All cats eat fish, Martin is a cat, Blub is a fish
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