Abduction

German Rigau i Claramunt
german.rigau@ehu.es
IXA group
Departamento de Lenguajes y Sistemas Informáticos
UPV/EHU

Outline

A -> B
A

B

Deduction	Induction	Abduction
A -> B	?	A -> B
A	A	?
?	B	B

Abduction

- We assume A because it explains B …

- Abduction is inference to the **best explanation**
- Has applications to diagnosis, plan recognition, natural language understanding, vision, and many other tasks.
- It is frequently formalized as constructing a set of assumptions that logically imply and therefore "explain" a set of observations.
- The process of finding the best explanation from a set of observations
- First used by C. S. Pierce (1955)

Abduction

- Abductive reasoning starts when an inquirer considers a set of seemingly unrelated facts, armed with the intuition that they are somehow connected
- Abduction is the process of inference that produces a hypothesis
  - Formation of plausible hypothesis
  - Selection of the best one

Abduction

- Given:
  - Backgound knowledge KB
  - Observations O
- Find:
  - Hypothesis H <u>such that</u>
    - KB U H $\nvdash \perp$
    - KB U H $\vdash$ O

- Multiple hypothesis H !
  - That explain O given KB
  - Usually depends on
    - the <u>size</u> (or <u>simplicity</u>) of H
    - the <u>coherence</u> of H (selects H that maximally connects O)

Abduction

- Abduction or Inference to the Best Explanation is a form of inference that follows a pattern like this:
  - D is a collection of data (facts, observations, givens),
  - H explains D (would, if true, explain D),
  - No other hypothesis explains D as well as H does.

  - Therefore, H is probably correct.

Abduction

- Extreme example of abduction from Eugene Ionesco's play “Rhinoceros” from the “Theater of the Absurd” school:

  - All cats die.
  - Socrates is dead.
  - Therefore, Socrates is a cat.

Abduction

- Textual Entailment (Recognizing Textual Entailment task, RTE)
  - T entails H, H is a consequent of T, T ⇒ H
    - Directional relationship between a coherent text T and H
    - If the meaning of H, as interpreted in the context of T, can be inferred from the meaning of T, as would typically be interpreted by people

  - T: Peter brings his car to the garage for repair
  - H: Peter's car is damaged
  - T ⇒ H

  - T: Corrosion caused intermittent electrical contact
  - H: Corrosion prevented continuous electrical contact
  - T ⇒ H

  - T: Marlowe opened the refrigerator
  - H: Marlowe was hungry
  - T ⇒ H

Abduction

- The strength of an abductive conclusion will in general depend on several factors, including:
  - how good H is by itself
    - independently of considering the alternatives
  - how decisively H surpasses the alternatives
  - how exhaustive the search was for alternative explanations, and
  - pragmatic considerations, including
    - the costs of being wrong and the benefits of being right,
    - how strong the need is to come to a conclusion at all, especially considering the possibility of seeking further evidence before deciding.

Abduction

- FOL based approaches to abduction
  - Determine the set of assumptions sufficient to deduce the observations
    - Unable to reason under uncertainty
    - Unable to estimate the likelihood of alternative explanations
- Bayesian Networks
  - KB is encoded as a directed graph
  - Given O probabilistic inference over the graph is done to compute the posterior probability of alternative explanations
    - Essentially Propositional Logic
    - Cannot handle structured representations
- Weighted abduction, TACITUS (Hobbs et al. 1993)
  - Finds the lowest weight explanation
  - No solid theoretical basis

Abduction

- Abduction using Markov Logic Networks (MLN)
  - (Kate & Mooney 2009)
  - Markov Logic Networks (Richarson & Domingos 2006)
  - Alchemy !
    - http://alchemy.cs.washington.edu/
  - Traditional FOL can be seen as hard constraints (0% vs. 100%)
  - MLN assigns a weight to each formula
  - The weight reflects how strong a constraint is
  - MLN is inherently deductive
  - MLN do not directly support abductive inference

Abduction

rained ⇒ *grass_is_wet*

sprinkler_was_on ⇒ *grass_is_wet*

- Observations:

grass_is_wet

- Adding reverse implications

grass_is_wet ⇒ *rained*

grass_is_wet ⇒ *sprinkler_was_on*

- Abductive inference by deduction …

sprinkler_was_on ~> *grass_is_wet* ~> *rained* (!)

- Both cannot be true …

grass_is_wet ⇒ ¬ *rained* ∨ ¬ *sprinkler_was_on*

Abduction

$$\forall X\,\forall Y(\text{mosquito}(X) \wedge \text{infected}(X,\text{malaria}) \wedge \text{bite}(X,Y) \Rightarrow \text{infected}(Y,\text{malaria}))$$

$$\forall X\,\forall Y(\text{infected}(X,\text{malaria}) \wedge \text{transfuse}(\text{blood},X,Y) \Rightarrow \text{infected}(Y,\text{malaria}))$$

- Observations:

$\text{infected}(\text{john},\ \text{malaria})$

$\text{transfuse}(\text{blood},\ \text{mary},\ \text{john})$

- MLNs do not directly support abductive inference
- In MLNs we need to explicitly include clauses with reverse implications

Abduction

$$\forall X\, \forall Y(mosquito(X) \land infected(X, malaria) \land bite(X, Y) \Rightarrow infected(Y, malaria))$$

Reverse implication:

$$\forall Y(infected(Y, malaria) \Rightarrow \exists X(mosquito(X) \land infected(X, malaria) \land bite(X, Y)))$$

$$\forall X\, \forall Y(infected(X, malaria) \land transfuse(blood, X, Y) \Rightarrow infected(Y, malaria))$$

Reverse implication:

$$\forall Y(infected(Y, malaria) \Rightarrow \exists X(infected(X, malaria) \land transfuse(blood, X, Y)))$$

If Y is infected with malaria then at least one of the possible explanations must be true:

$$\forall Y(infected(Y, malaria) \Rightarrow \\ (\exists X(mosquito(X) \land infected(X, malaria) \land bite(X, Y))) \lor \\ (\exists X(infected(X, malaria) \land transfuse(blood, X, Y))))$$

But both explanations cannot be true:

$$\forall Y(infected(Y, malaria) \Rightarrow \\ \neg(\exists X(mosquito(X) \land infected(X, malaria) \land bite(X, Y))) \lor \\ \neg(\exists X(infected(X, malaria) \land transfuse(blood, X, Y))))$$

Abduction

- The Boston office called.

- There is an office “in” Boston (city)
- Somebody (person) works for/at the office
- The “in” relation can be expressed by a compound nominal
- An organization can play the role of the persons working for it

Abduction

German Rigau i Claramunt
german.rigau@ehu.es
IXA group
Departamento de Lenguajes y Sistemas Informáticos
UPV/EHU