PROPERTIES OF INFERENCES

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Common properties

Given explicit information

Implicit information made explicit

Limited resources

Goal-orientedness

PROPERTIES OF INFERENCES

Common properties

Given explicit information

Implicit information made explicit

Limited resources

Goal-orientedness

Distinct Properties

Reasoning technique

Reasoning strength

Context

EXAMPLES OF RULES

1) **If a town has more than 100,000 inhabitants, it is city.**

2) **If the patient is male, he cannot be pregnant.**

3) **If the employee is a group leader, he has a secretary.**

4) **If the tank is empty, the car cannot drive.**

5) **If the machine does not run, first check the power supply.**

6) **If the position of the broken piece is unknown, and wet spots are observed, this could be the position of the broken piece.**

EXAMPLES OF RULES

1) **If a town has more than 100,000 inhabitants, it is city.**

Identification

2) **If the patient is male, he cannot be pregnant.**

World Knowledge

3) **If the employee is a group leader, he has a secretary.**

Domain Knowledge

4) **If the tank is empty, the car cannot drive.**

Causality

5) **If the machine does not run, first check the power supply.**

Meta Rule

6) **If the position of the broken piece is unknown, and wet spots are observed, this could be the position of the broken piece.**

Self Reference

WHAT RULES DO NOT REPRESENT

Compiled knowledge encoded in rules

Sufficient for pure performance

Conceptual and mechanical issues mixed up

Limitations for documentation

Optimizations required – omitting trivial steps

Degree of detail hard to manage

Limitations in representations

No social environment expressed

No justifications for rule (experts know that)

No (domain-independent) strategic principles

REASONING PARADIGMS

Deduction

Abduction

Non-monotonic Reasoning

Reasoning under Uncertainty

PROPERTIES OF DEDUCTION

A deductive inference

(1) If it rains, the street is wet

(2) It rains

(3) The street is wet

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Concluding (3) from (1) and (2) ***Modus ponens***

Concluding ¬(2) from (1) and ¬(3) ***Modus tollens***

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Concluding (3) from (1) and (2) ***Modus ponens***

Concluding ¬(2) from (1) and ¬(3) ***Modus tollens***

Crucial Properties

Semi-decidability – logical soundness

Limited expressibility (1st order)

Limited use in reality

PROPERTIES OF ABDUCTION

An abductive inference

(1) If it rains, the street is wet

(2) It rains

---

(3) The street is wet

PROPERTIES OF ABDUCTION

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Generates hypotheses for explanations

PROPERTIES OF ABDUCTION

An abductive inference

(1) If it rains, the street is wet

(2) It rains

(3) The street is wet

Concluding (2) from (1) and (3)

Generates hypotheses for explanations

Crucial Properties

Defeasible

Extendable by plausibility weights

Widely useful in reality

PROPERTIES OF NON-MONOTONIC REASONING

A non-monotonic inference

(1) If it rains, the street is wet (unless we are in a tunnel, …)

(2) It rains

---

(3) The street is wet

PROPERTIES OF NON-MONOTONIC REASONING

A non-monotonic inference

(1) If it rains, the street is wet (unless we are in a tunnel, …)

(2) It rains

(3) The street is wet

Concluding (3) from (1) and (2)

Hypotheses defaults until better evidence

PROPERTIES OF NON-MONOTONIC REASONING

A non-monotonic inference

(1) If it rains, the street is wet (unless we are in a tunnel, …)

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(3) The street is wet

Concluding (3) from (1) and (2)

Hypotheses defaults until better evidence

Crucial Properties

Defeasible

Cognitively plausible representation

Widely useful in reality

PROPERTIES OF REASONING WITH UNCERTAINTY

A uncertainty-based inference

(1)	**If it rains, the street is wet**	**(p)**
(2)	**It rains**	**(q)**
(3)	**The street is wet**	**f(p,q)**

PROPERTIES OF REASONING WITH UNCERTAINTY

A uncertainty-based inference

(1)	**If it rains, the street is wet**	**(p)**
(2)	**It rains**	**(q)**
(3)	**The street is wet**	**f(p,q)**

Concluding (3) from (1) and (2)

Likelyhood of facts derived

PROPERTIES OF REASONING WITH UNCERTAINTY

A uncertainty-based inference

(1) If it rains, the street is wet (p)

(2) It rains (q)

(3) The street is wet f(p,q)

Concluding (3) from (1) and (2)

Likelyhood of facts derived

Crucial Properties

Semantics may be problematic

Computation sometimes problematic

Useful for many tasks in reality

WHAT IS A RULE?

Components of a rule

- **Precondition (if …*)***
- **Postcondition or action (then …*)***

Examples

If an accident has happened, call the ambulance

If the pH-value of the material is below 6, this is an acid.

The precondition determines the applicability of a rule

The postcondition determines additionally derived knowledge (applicable actions)

There are two types of rules:

- ***Implications*** **(*deduction*), deriving the truth of a fact**
- ***Actions*, which change a state**

This distinction is essential for commutative rule systems (not for action-like rules)

DERIVATION STRATEGIES

Two principled choices

- ***Forward reasoning***

  Starting from the given database, one of those rules whose precondition is fulfilled, is selected, and its action part is executed, which changes the database. This process is repeated until a termination criterion is fulfilled, or no more rules are applicable.

  This strategy is suitable only to perform inferences from a given database.

- ***Backward reasoning***

  Starting from a goal, only those rules will be taken into account whose action part contains the goal. Unknown parameters of the precondition are derived recursively, or the user is consulted.

  This strategy is suitable to perform inferences from a given database and to query unknown facts in a goal-oriented manner.

FORWARD CHAINING

***Selection* among *multiple* applicable rules:**

- ***Preselection:* determining the set of applicable rules (the *conflict set*)**
- ***Selection:* choosing one rule of the conflict set by a *conflict resolution strategy***

The most important *conflict resolution strategies* are:

- **Selection according to some *order*, such as the *first* rule or the *most recent* one**
- **Selection according to the *syntactic* structure of a rule, such as the *more specific* rule or the *syntactically bigger* one**
- **Selection according to *additional knowledge*, such as pre-given *priority* or through *other rules* (meta rules)**

Changes for *backward* chaining

- **Choice between derivation and consultation**
- **The more *precise* the goal, the *smaller* the search space**

WHAT IS A CONSTRAINT?

Components of a constraint

- **A set of variables**
- **A set of values relating variables to each other**

Examples

Jim is 5 years older than John

Subject and verb agree in number and person

Constraint problem

Solutions to a constraint problem are assignments of values to variables so that all constraints are fulfilled

Applications

Physical laws, algebraic equations, unification grammars, …

COMPARING RULES AND CONSTRAINT?

Evaluation of information

- **Rules are directed, constraints not**
- **Restricted evaluation potential for rules**

Efficiency

Restricted interpretation enables more efficient evaluation for rules

Advantages/disadvantages

- **Rules are more modular and easier to adapt**
- **Constraints enable better information evaluation**
- **Both are associated with a flow of control that is difficult to understand**

Application areas

- **Rules suited for domain with isolated knowledge**
- **Constraints suited for coherent (causal) theories**

PARTIAL PLAN FOR THE LECTURE

Modeling with rules

Deduction systems

Deductive databases

Deduction in NLP

Digital Aristotle

Basics of non-monotonic logic

Argumentation

Non-monotonic reasoning in NL generation

Abductive and model-based diagnosis

Abduction in NL interpretation

Quantitative reasoning (fuzzy logic, belief networks)