

CS 2710 Foundations of AI Lecture 14-b

Uncertainty

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KB systems. Medical example.

We want to build a KB system for the **diagnosis of pneumonia**.

Problem description:

- **Disease:** pneumonia
- **Patient symptoms (findings, lab tests):**
 - Fever, Cough, Paleness, WBC (white blood cells) count, Chest pain, etc.

Representation of a patient case:

- Statements that hold (are true) for the patient.

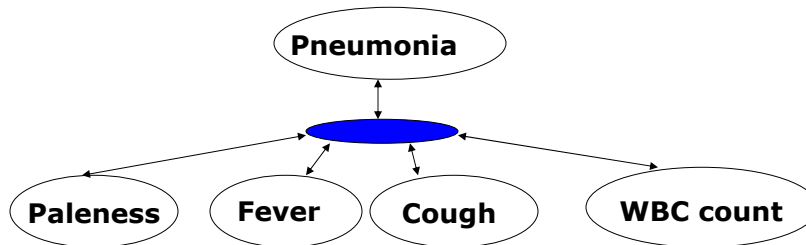
E.g: Fever =*True*
 Cough =*False*
 WBCcount=*High*

Diagnostic task: we want to decide whether the patient suffers from the pneumonia or not given the symptoms

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Uncertainty

To make diagnostic inference possible we need to represent knowledge (axioms) that relate symptoms and diagnosis



Problem: disease/symptoms relations are not deterministic

- They are **uncertain (or stochastic) and** vary from patient to patient

Uncertainty

Two types of uncertainty:

- **Disease → Symptoms uncertainty**

- A patient suffering from pneumonia may not have fever all the times, may or may not have a cough, white blood cell test can be in a normal range.

- **Symptoms → Disease uncertainty**

- High fever is typical for many diseases (e.g. bacterial diseases) and does not point specifically to pneumonia
- Fever, cough, paleness, high WBC count combined do not always point to pneumonia

Uncertainty

Why are relations uncertain?

- **Observability**

- It is impossible to observe all relevant components of the world
- Observable components behave stochastically even if the underlying world is deterministic

- **Efficiency, capacity limits**

- It is often impossible to enumerate and model all components of the world and their relations
- abstractions can become stochastic

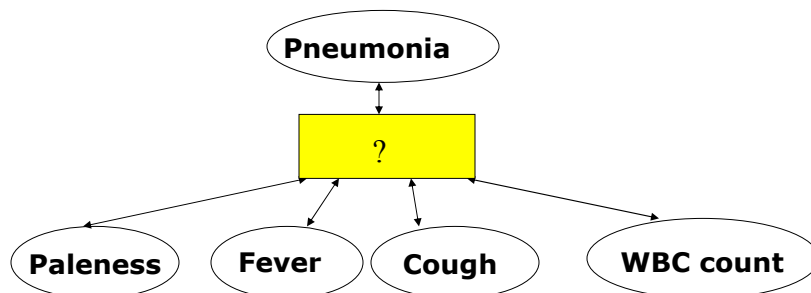
Humans can reason with uncertainty !!!

- Can computer systems do the same?

Modeling the uncertainty.

Key challenges:

- How to represent the relations in the presence of uncertainty?
- How to manipulate such knowledge to make inferences?
 - **Humans can reason with uncertainty.**



Methods for representing uncertainty

Extensions of the propositional and first-order logic

- Use, uncertain, imprecise statements (relations)

Example: Propositional logic with certainty factors

Very popular in 70-80s in knowledge-based systems (MYCIN)

- **Facts (propositional statements)** are assigned a **certainty value** reflecting the belief in that the statement is satisfied:

$$CF(Pneumonia = True) = 0.7$$

- **Knowledge:** typically in terms of **modular rules**

If	1. The patient has cough, and 2. The patient has a high WBC count, and 3. The patient has fever
Then	with certainty 0.7 the patient has pneumonia

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Certainty factors

Problem 1:

- Chaining of multiple inference rules (propagation of uncertainty)

Solution:

- **Rules** incorporate tests on the **certainty values**

$$(A \text{ in } [0.5,1]) \wedge (B \text{ in } [0.7,1]) \rightarrow C \text{ with } CF = 0.8$$

Problem 2:

- Combinations of rules **with the same conclusion**

$$(A \text{ in } [0.5,1]) \wedge (B \text{ in } [0.7,1]) \rightarrow C \text{ with } CF = 0.8$$

$$(E \text{ in } [0.8,1]) \wedge (D \text{ in } [0.9,1]) \rightarrow C \text{ with } CF = 0.9$$

- What is the resulting $CF(C)$?

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Certainty factors

- **Combination of multiple rules**

$(A \text{ in } [0.5,1]) \wedge (B \text{ in } [0.7,1]) \rightarrow C$ with $CF = 0.8$

$(E \text{ in } [0.8,1]) \wedge (D \text{ in } [0.9,1]) \rightarrow C$ with $CF = 0.9$

- **Three possible solutions**

$$CF(C) = \max[0.9; 0.8] = 0.9$$

$$CF(C) = 0.9 * 0.8 = 0.72$$

$$CF(C) = 0.9 + 0.8 - 0.9 * 0.8 = 0.98$$

} ?

Problems:

- Which solution to choose?
- All three methods break down after a sequence of inference rules

Methods for representing uncertainty

Probability theory

- A well defined theory for modeling and reasoning in the presence of uncertainty
- A natural choice to replace certainty factors

Facts (propositional statements)

- Are represented via **random variables** with two or more values

Example: *Pneumonia* is a random variable

values: True and False

- Each value can be achieved **with some probability:**

$$P(\text{Pneumonia} = \text{True}) = 0.001$$

$$P(\text{WBCcount} = \text{high}) = 0.005$$