CS 1571 Introduction to AI
Lecture 17b

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:

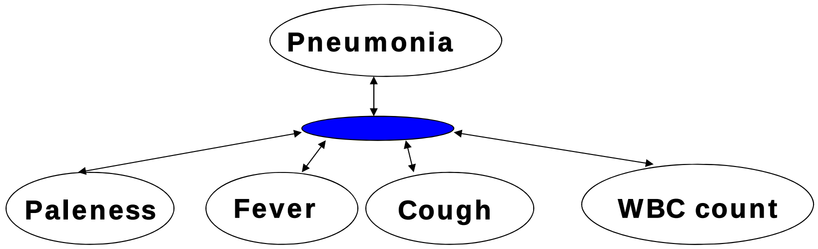
- Statements that hold (are true) for the patient.

  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

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 make the relations stochastic

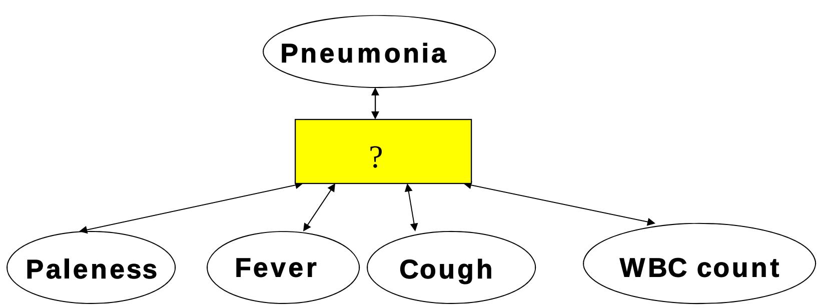
Humans can reason with uncertainty !!!

- 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

Certainty factors

Problem 1:

- Chaining of multiple inference rules (propagation of uncertainty)

Solution:

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

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

Problem 2:

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

$$(A \text{ in } [0.5,1]) \wedge (B \text{ in } [0.7,1]) \rightarrow C \text{ with } \mathrm{CF} = 0.8$$
$$(E \text{ in } [0.8,1]) \wedge (D \text{ in } [0.9,1]) \rightarrow C \text{ with } \mathrm{CF} = 0.9$$

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

Certainty factors

- **Combination of multiple rules**

$$(A \text{ in } [0.5,1]) \wedge (B \text{ in } [0.7,1]) \rightarrow C \text{ with CF} = 0.8$$
$$(E \text{ in } [0.8,1]) \wedge (D \text{ in } [0.9,1]) \rightarrow C \text{ with CF} = 0.9$$

- **Three possible solutions**

$$\left.\begin{array}{l} CF(C) = \max[0.9;0.8] = 0.9 \\ CF(C) = 0.9 * 0.8 = 0.72 \\ CF(C) = 0.9 + 0.8 - 0.9 * 0.8 = 0.98 \end{array}\right\} \textbf{?}$$

Problems:

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