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[DΣIM]

Approximate Reasoning

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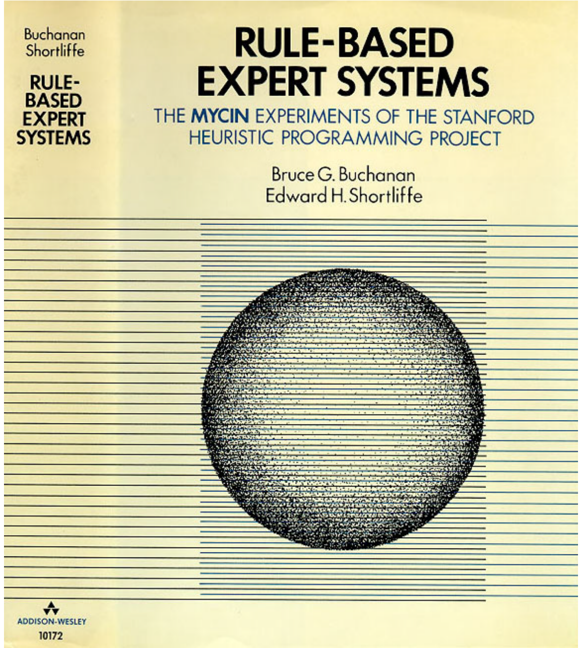
Certainty Factors
MYCIN

MESIIA – MIA

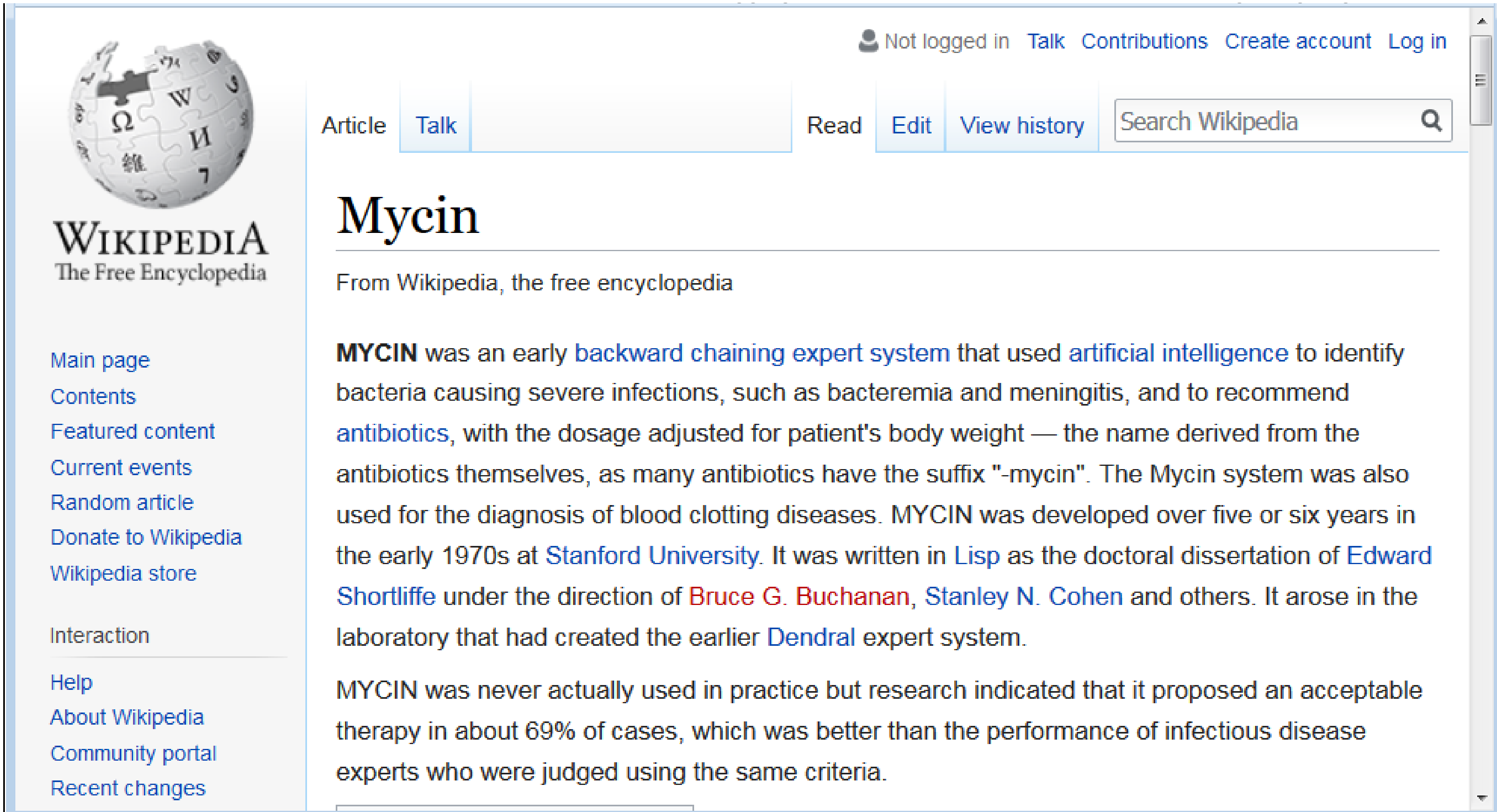
Introduction

- Certainty Factors is a well-known a quasi-probabilistic model that is founded on the classic probability theory.
- It is one of the pioneer techniques for approximate reasoning.
- It was defined in the MYCIN

expert system.



Introduction



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Mycin

From Wikipedia, the free encyclopedia

MYCIN was an early backward chaining expert system that used artificial intelligence to identify bacteria causing severe infections, such as bacteremia and meningitis, and to recommend antibiotics, with the dosage adjusted for patient's body weight — the name derived from the antibiotics themselves, as many antibiotics have the suffix "-mycin". The Mycin system was also used for the diagnosis of blood clotting diseases. MYCIN was developed over five or six years in the early 1970s at Stanford University. It was written in Lisp as the doctoral dissertation of Edward Shortliffe under the direction of Bruce G. Buchanan, Stanley N. Cohen and others. It arose in the laboratory that had created the earlier Dendral expert system.

MYCIN was never actually used in practice but research indicated that it proposed an acceptable therapy in about 69% of cases, which was better than the performance of infectious disease experts who were judged using the same criteria.

Motivation

- The Bayesian model based on probabilities makes some assumptions that sometimes are not appropriate for the experts.
- For example,

$$p(c|e) = x \Rightarrow p(\neg c|e) = 1 - x$$

  - The probability of the conclusion and its negation gives a sum of 1. But some experts argue that a decrease in the confidence about one conclusion *c*, does not increase the confidence in its contrary.

Certainty Factors

- MYCIN expert system introduced the CF model (1970s).
- It is based on calculating two measures:
  - Measure of Belief: MB
  - Measure of Disbelief: MD

$$e \xrightarrow{MB(c,e),\, MD(c,e)} c$$

Certainty Factors

- Measure of Belief: MB

$$MB(c,e) = \begin{cases} 1 & if \quad p(c)=1 \\ \dfrac{\max\left(p(c\mid e), p(c)\right) - p(c)}{1-p(c)} & if \quad p(c)\neq 1 \end{cases}$$

- Measure of Disbelief: MD

$$MD(c,e) = \begin{cases} 1 & if \quad p(c)=0 \\ \dfrac{p(c) - \min\left(p(c\mid e), p(c)\right)}{p(c)} & if \quad p(c)\neq 0 \end{cases}$$

Certainty Factors. Properties of MB and MD

1. Both values are in [0,1]
2. If $MB(c,e) > 0 \Rightarrow MD(c,e) = 0$. In this case the evidences increase the belief about the conclusion c.
3. If $MD(c,e) > 0 \Rightarrow MB(c,e) = 0$. In this case the evidences decrease the confidence about c.

Therefore, a certain evidence cannot increase and decrease the confidence at the same time.

Certainty Factors

- Both measures can be combined into CF as:

$$CF(c,e) = \frac{MB(c,e) - MD(c,e)}{1 - \min\left(MB(c,e), MD(c,e)\right)}$$

IF <evidence e> THEN <conclusion c> {CF_{rule}}

where *CF* represents belief in conclusion c
given that evidence *e* has occurred.

- Properties:
  1. CF is in [-1,1]
  2. If $CF(c,e) > 0$ the evidence increases the belief about c
  3. If $CF(c,e) < 0$ the evidence decreases the belief about c

Certainty Factors

- The certainty factor assigned by a rule is propagated through the rule. This involves establishing the net certainty of the rule consequent when the evidence in the rule antecedent is uncertain:

$$CF(c) = CF(e) \times CF(c,e)$$

For example:

IF sky is clear

THEN the forecast is sunny {CF_{rule} 0.8}

and the current certainty factor of *sky is clear* is 0.5, then

$CF(c) = 0.5 \times 0.8 = 0.4$

This result can be interpreted as "It may be sunny".

Certainty Factors. Combination rules.

- For **conjunctive rules** such as:

IF <evidence e1>
AND <evidence e2> AND …
THEN <conclusion c> {CF}

the certainty of conjunction of evidences is:

$$CF\,(e_1 \cap e_2 \cap \ldots \cap e_n) = min\,[CF\,(e_1), CF\,(e_2), \ldots, CF\,(e_n)]$$

For example:

IF sky is clear AND the forecast is sunny
THEN the action is 'wear sunglasses' {*CF*=0.8}

and the certainty of **sky is clear is 0.9** and the certainty of the forecast of **sunny is 0.7**, then

$CF(c, e_1 \cap e_2) = min\,[0.9, 0.7] \times 0.8 = 0.7 \times 0.8 = 0.56$

Certainty Factors

- For **disjunctive rules** such as:

IF <evidence e1>
  OR <evidence e2> OR …
THEN <conclusion c> {CF}

the certainty of disjunction of the evidences is:

$$CF\ (e_1 \cup e_2 \cup \ldots \cup e_n) = max\ [CF\ (e_1), CF\ (e_2), \ldots, CF\ (e_n)]$$

For example:

IF sky is overcast OR the forecast is rain
THEN the action is 'take an umbrella' {*CF*=0.9}

and the certainty of **sky is overcast is 0.8** and the certainty of the forecast of **rain is 0.5**, then

$CF(c, e_1 \cup e_2) = max\ [0.8, 0.5] \times 0.9 = 0.8 \times 0.9 = 0.72$

Certainty Factors. Combination rules.

- When the same consequent is obtained as a result of the execution of two or more rules, the individual certainty factors of these rules must be merged to give a combined certainty factor for a hypothesis.

Rule 1:	IF	A is X
	THEN	C {CF=0.8}
Rule 2:	IF	B is Y
	THEN	C {CF=0.6}

- What certainty should be assigned C if both Rule 1 and Rule 2 are fired?

Certainty Factors. Parallel combination rule.

To calculate a combined certainty factor from two others we must consider three cases, depending on the sign of the two CF values that are combined.

$$CF(c) = CF1(c)\ combined\ CF2(c) = \begin{cases} CF1 + CF2(1 - CF1) & CF1 > 0\ \&\ CF2 > 0 \\ CF1 + CF2(1 + CF1) & CF1 < 0\ \&\ CF2 < 0 \\ \dfrac{CF1 + CF2}{1 - \min(|CF1|, |CF2|)} & otherwise \end{cases}$$

This combination rule is commutative and associative
It must be applied only to two inputs (in pairs)

Bayesian reasoning vs Certainty Factors

- The certainty factors theory provides a practical alternative to classic Bayes theorem in probability.
- The heuristic manner of combining certainty factors is different from the manner in which they would be combined if they were probabilities.
- The certainty theory is not “mathematically pure” but does mimic the thinking process of a human expert.

Probabilistic reasoning vs Certainty Factors

- The probabilistic method is likely to be the most appropriate if reliable statistical data exists.

- In the absence of any of the specified conditions, the probabilistic approach might be too arbitrary and even biased to produce meaningful results.

- Although the certainty factors approach lacks the mathematical correctness of the probability theory, it outperforms probabilistic reasoning in real application areas, such as medical diagnostics.

Additional Readings

- Artificial Intelligence. A new synthesis. Nils. J. Nilsson, Morgan-Kauffman, 1998 (part III). (004.8 Nil at URV in Spanish)

- Artificial Intelligence. Elaine Rich & Kevin Knight. Ed. Mc-Graw Hill, 1991. Chapter 8 (004.8 Ric at URV)
- See paper in Moodle from:

https://www.microsoft.com/en-us/research/wp-content/uploads/2016/11/The-Certainty-Factor-Model.pdf