CERTAINTY FACTORS

Expert System Lab Work

Lecture #6
Uncertainty

There is a uncertainty in the mind of experts when make a decision accordance their expertise.
Representation Uncertainty

- Basis Concept of Probability
- Certainty Factor
- Bayesian Reasoning
- Fuzzy
- Neural Network
- Genetic Algorithm
Causes of Uncertainty

- Not completely and uncertainty information
- Unknown data
- Unify the different of viewpoint of experts
- Imprecise language (always, often, seldom, some times)
Causes Uncertainty

Imprecise language

<table>
<thead>
<tr>
<th>Term</th>
<th>Mean value</th>
<th>Term</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>99</td>
<td>Always</td>
<td>100</td>
</tr>
<tr>
<td>Very often</td>
<td>88</td>
<td>Very often</td>
<td>87</td>
</tr>
<tr>
<td>Usually</td>
<td>85</td>
<td>Usually</td>
<td>79</td>
</tr>
<tr>
<td>Often</td>
<td>78</td>
<td>Often</td>
<td>74</td>
</tr>
<tr>
<td>Generally</td>
<td>78</td>
<td>Rather often</td>
<td>74</td>
</tr>
<tr>
<td>Frequently</td>
<td>73</td>
<td>Frequently</td>
<td>72</td>
</tr>
<tr>
<td>Rather often</td>
<td>65</td>
<td>Generally</td>
<td>72</td>
</tr>
<tr>
<td>About as often as not</td>
<td>50</td>
<td>About as often as not</td>
<td>50</td>
</tr>
<tr>
<td>Now and then</td>
<td>20</td>
<td>Now and then</td>
<td>34</td>
</tr>
<tr>
<td>Sometimes</td>
<td>20</td>
<td>Sometimes</td>
<td>29</td>
</tr>
<tr>
<td>Occasionally</td>
<td>20</td>
<td>Occasionally</td>
<td>28</td>
</tr>
<tr>
<td>Once in a while</td>
<td>15</td>
<td>Once in a while</td>
<td>22</td>
</tr>
<tr>
<td>Not often</td>
<td>13</td>
<td>Not often</td>
<td>16</td>
</tr>
<tr>
<td>Usually not</td>
<td>10</td>
<td>Usually not</td>
<td>16</td>
</tr>
<tr>
<td>Seldom</td>
<td>10</td>
<td>Seldom</td>
<td>9</td>
</tr>
<tr>
<td>Hardly ever</td>
<td>7</td>
<td>Hardly ever</td>
<td>8</td>
</tr>
<tr>
<td>Very seldom</td>
<td>6</td>
<td>Very seldom</td>
<td>7</td>
</tr>
<tr>
<td>Rarely</td>
<td>5</td>
<td>Rarely</td>
<td>5</td>
</tr>
<tr>
<td>Almost never</td>
<td>3</td>
<td>Almost never</td>
<td>2</td>
</tr>
<tr>
<td>Never</td>
<td>0</td>
<td>Never</td>
<td>0</td>
</tr>
</tbody>
</table>
Certainty Theory

- Certainty factor (cf), value to measure degree of belief from expert.
- Maximum value of cf is +1.0 (definitely true) and minimum -1.0 (definitely false).

Two aspects:
- Certainty in the Evidence
  - *The evidence can have a certainty factor attached*
- Certainty in Rule
1. Model ‘Net Belief’ (Shortliffe dan Buchanan)

**CF (Rule) = MB(H,E) - MD(H,E)**

\[
MB(H,E) = \begin{cases} 
1 & \text{if } P(H) = 1 \\
\max[P(H|E), P(H)] - P(H)/1 - P(H) & \text{Otherwise}
\end{cases}
\]

\[
MD(H,E) = \begin{cases} 
1 & \text{if } P(H) = 0 \\
\min[P(H|E), P(H)] - P(H)/1 - P(H) & \text{Otherwise}
\end{cases}
\]
## Certainty Factors

### 2. Direct Interview with Expert

<table>
<thead>
<tr>
<th>Uncertain Term</th>
<th>Certainty Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely not</td>
<td>-1.0</td>
</tr>
<tr>
<td>Almost certainly not</td>
<td>-0.8</td>
</tr>
<tr>
<td>Probably not</td>
<td>-0.6</td>
</tr>
<tr>
<td>Maybe not</td>
<td>-0.4</td>
</tr>
<tr>
<td>Unknown</td>
<td>-0.2 to +0.2</td>
</tr>
<tr>
<td>Maybe</td>
<td>+0.4</td>
</tr>
<tr>
<td>Probably</td>
<td>+0.6</td>
</tr>
<tr>
<td>Almost certainly</td>
<td>+0.8</td>
</tr>
<tr>
<td>Definitely</td>
<td>+1.0</td>
</tr>
</tbody>
</table>
Example:

Expert: "If headache and have a cold and fever, then most possibility is influenza"

Rule: IF evidence 1= headache AND evidence 2= have a cold AND evidence 3= fever

THEN seek=influenza

(cf = 0.8)
In Expert System with CF, knowledge base composed of set of rules with syntax:

IF <evidence>
THEN <hypothesis> \{ cf \}

CF refers to degree of belief for hypothesis H when evidence E occurred.
Example

- Degree of belief for hypothesis $H$ when evidence $E$ occurred.
  - $\text{cf} \ (H,E) = \text{cf} \ (E) * \text{cf}(\text{Rule})$

- e.g:
  IF    sky is clear
  THEN  the forecast is sunny \{cf 0.8\}

- With cf of “sky is clear” is 0.5
  - $\text{cf} \ (H,E) = 0.5 \times 0.8 = 0.4$
Multiple Antecedents

- How the CF if we have two evidence?
  - With conjunction (i.e. and)
    - Use minimum $cf$ of evidence
  - With disjunction (i.e. or)
    - Use maximum $cf$ of evidence
Conjunctive Antecedents - Example

- Conjunctive Rules:
  \[
  cf(H, E_1 \text{ and } E_2 \text{ and } \ldots E_i) = \min\{cf(E_1, E_2, \ldots E_i)\}
  \]
  *cf(Rule)

  IF there are dark clouds \( E_1 \)
  AND the wind is stronger \( E_2 \)
  THEN it will rain \( \{cf \, 0.8\} \)

- If \( cf(E_1) = 0.5 \) and \( cf(E_2) = 0.9 \), then

  \[
  cf(H, E) = \min\{0.5, 0.9\} \times 0.8 = 0.4
  \]
Disjunctive Antecedents - Example

- **Disjunctive Rules:**
  \[
  \text{cf}(H, E_1 \text{ or } E_2 \text{ or } \ldots E_i) = \max\{\text{cf}(E_1, E_2, \ldots E_i)\} \\
  \ast \text{cf(Rule)}
  \]

- IF there are dark clouds \( E_1 \)
- OR the wind is stronger \( E_2 \)
- THEN it will rain \{cf 0.8\}

- If \( \text{cf}(E_1) = 0.5 \) and \( \text{cf}(E_2) = 0.9 \), then
  \[
  \text{cf}(H, E) = \max\{0.5, 0.9\} \ast 0.8 = 0.72
  \]
Similarly Concluded Rules

How to determine CF if two rules have similar conclusion?

Rule 1:
IF weatherperson predicts rain ($E_1$) THEN it will rain
{cf$_1$ 0.7}

Rule 2:
IF farmer predicts rain ($E_2$) THEN it will rain
{cf$_2$ 0.9}
Similarly Concluded Rules - Example

Two rules with similar conclusion:

IF weatherperson predicts rain \( E_1 \)
THEN it will rain
\{cf_1 \, 0.7\}

Suppose \( cf(E_1) = 1.0 \) and \( cf(E_2) = 1.0 \)

\[
\begin{align*}
\text{cf}_1(H_1, E_1) &= \text{cf}(E_1) \times \text{cf}(\text{Rule}_1) \\
&= 1.0 \times 0.7 = 0.7
\end{align*}
\]

IF farmer predicts rain \( E_2 \)
THEN it will rain
\{cf_2 \, 0.9\}

\[
\begin{align*}
\text{cf}_2(H_2, E_2) &= \text{cf}(E_2) \times \text{cf}(\text{Rule}_2) \\
&= 1.0 \times 0.9 = 0.9
\end{align*}
\]
Similarly Concluded Rules

Formula:

\[
CF_c(CF_1, CF_2) =
\begin{align*}
& CF_1 + CF_2(1 - CF_1) & \text{if both } > 0 \\
& CF_1 + CF_2(1 + CF_1) & \text{if both } < 0 \\
& CF_1 + CF_2 / (1 - \min(|CF_1|, |CF_2|)) & \text{if one } < 0
\end{align*}
\]
Similarly Concluded Rules

New CF value from facts above can be formulated:

\[ cf(\text{cf1}, \text{cf2}) = \text{cf1} + \text{cf2}(1 - \text{cf1}) \]

\[ = 0.7 + 0.9(1 - 0.7) \]

\[ = 0.97 \]
EXERCISE

Determine New Value of CF from some facts in below:

1. IF fever
   THEN typhus \{cf -0.39\}

2. IF amount of thrombosis is low
   THEN typhus \{cf -0.51\}

3. IF the body is weak
   THEN typhus \{cf 0.87\}

4. IF diarrhea/constipation
   THEN typhus \{cf 0.63\}
Combining CF with CLIPS

(defrule start
  (declare (salience 1000))
  (initial-fact)
  =>
  (set-fact-duplication TRUE))
Combining CF with CLIPS

(defrule both-positif
  ?fact1<- (pasien ?sakit ?tifus \(c_1\&:1\geq \(c_1\ 0\))
  ?fact2<- (pasien ?sakit ?tifus \(c_2\&:1\geq \(c_2\ 0\))
  (test (neq ?fact1 ?fact2))
=>
  (retract ?fact1 ?fact2)
  (bind \(c_3\ (- (+ \(c_1\ \(c_2\) (* \(c_1\ \(c_2))))
  (assert (pasien ?sakit ?tifus \(c_3\)))
}
(defrule both-negatif
 ?fact1<- (pasien ?sakit ?tifus ?c1 & :(< ?c1 0))
 (test (neq ?fact1 ?fact2))
 =>
 (retract ?fact1 ?fact2)
 (bind ?c3 (+ (+ ?c1 ?c2) (* ?c1 ?c2)))
 (assert (pasien ?sakit ?tifus ?c3)))
(defrule opposite-sign
  ?fact1<- (pasien ?sakit ?tifus ?c1)
  (test (< (* ?c1 ?c2) 0))
  (test (neq ?fact1 ?fact2))
  =>
  (retract ?fact1 ?fact2)
  (bind ?c3 (/ (+ ?c1 ?c2) (- 1 (min (abs ?c1) (abs ?c2)))))
  (assert (pasien ?sakit ?tifus ?c3)))
Combining CF with CLIPS

(deffacts rumahsakit
(pasien sakit tifus -0.39)
(pasien sakit tifus -0.51)
(pasien sakit tifus 0.87)
(pasien sakit tifus 0.63))
Lakukan Beberapa Langkah

- Load -> Reset -> (agenda)
- Perhatikan urutan *rule* yang dijalankan

Rule dengan Salience yang lebih besar akan dieksekusi terlebih dahulu
Modifikasi Salience dari Rule

(defrule both-positif
  (declare (salience 6)
    ....
    ....
    ....
)

(defrule both-negatif
  (declare (salience 10)
    ....
    ....
    ....
)
Lakukan langkah yang sama : Load -> Reset -> Agenda

Lihat pada Agenda:

Akan terlihat bahwa rule dengan salience tinggi, akan dijalankan terlebih dahulu
Combining CF with CLIPS

\[ Cf = 0.8390766 \]