

Certainty Factor

- certainty factor CF
 - ranges between -1 (denial of the hypothesis H) and +1 (confirmation of H)
 - allows the ranking of hypotheses
- difference between belief and disbelief
$$CF(H,E) = MB(H,E) - MD(H,E)$$
- combining antecedent evidence
 - use of premises with less than absolute confidence
 - $E_1 \wedge E_2 = \min(CF(H, E_1), CF(H, E_2))$
 - $E_1 \vee E_2 = \max(CF(H, E_1), CF(H, E_2))$
 - $\neg E = \neg CF(H, E)$

21

Combining Certainty Factors

- certainty factors that support the same conclusion
- several rules can lead to the same conclusion
- applied incrementally as new evidence becomes available

$CF_c(CF_1, CF_2) =$

$$CF_1 + CF_2(1 - CF_1) \quad \text{if both } > 0$$

$$CF_1 + CF_2(1 + CF_1) \quad \text{if both } < 0$$

$$CF_1 + CF_2 / (1 - \min(|CF_1|, |CF_2|)) \quad \text{if one } < 0$$

22

Characteristics of Certainty Factors

<i>Aspect</i>	Probability	M B	M D	C F
<i>Certainly true</i>	$P(H E) = 1$	1	0	1
<i>Certainly false</i>	$P(\neg H E) = 1$	0	1	-1
<i>No evidence</i>	$P(H E) = P(H)$	0	0	0

Ranges

measure of belief	$0 \leq \mathbf{MB} \leq 1$
measure of disbelief	$0 \leq \mathbf{MD} \leq 1$
certainty factor	$-1 \leq \mathbf{CF} \leq +1$

23

CLIPS Example: Combining Certainty Factors

Assume we are given the following initial facts:

; (<object> <attribute> <value> <certainty-factor>)

```
(defacts initial-organism-facts
  (organism stain gramneg 0.3)
  (organism stain gramneg 0.3)
  (organism stain gramneg 0.5)
  (organism stain gramneg -0.5)
  (organism stain gramneg 0.4)
  (organism morpholgy rod 0.7)
  (organism morpholgy rod -0.6)
  (patient is-a compromised-host 0.8))
```

24

According to the MYCIN expert system, the following rules must be applied when combining the initial identical facts with a new Certainty Factor (CF):

New CF = (CF1+CF2) – (CF1*CF2) if both CF1 and CF2 are positive

New CF = (CF1+CF2) + (CF1*CF2) if both CF1 and CF2 are negative

New CF = $\frac{(CF1+CF2)}{1 - \min(|CF1|, |CF2|)}$ if CF1 and CF2 have opposite signs

25

; Allow facts that are duplicates:

(defrule start

(declare (salience 1000))

(initial-fact)

=>

(set-fact-duplication TRUE))

(defrule combine-certainties-both-positive

?fact1 <- (organism ?attribute ?value ?C1&:(>= ?C1 0))

?fact2 <- (organism ?attribute ?value ?C2&:(>= ?C2 0))

(test (neq ?fact1 ?fact2))

=>

(retract ?fact1 ?fact2)

(bind ?C3 (- (+ ?C1 ?C2) (* ?C1 ?C2)))

(assert (organism ?attribute ?value ?C3)))

26

```
(defrule combine-certainties-both-negative
  ?fact1 <- (organism ?attribute ?value ?C1&:(< ?C1 0))
  ?fact2 <- (organism ?attribute ?value ?C2&:(< ?C2 0))
  (test (neq ?fact1 ?fact2))
=>
  (retract ?fact1 ?fact2)
  (bind ?C3 (+ (+ ?C1 ?C2) (* ?C1 ?C2)))
  (assert (organism ?attribute ?value ?C3)))
```

27

```
(defrule combine-certainties-with-opposite-signs
  ?fact1 <- (organism ?attribute ?value ?C1)
  ?fact2 <- (organism ?attribute ?value ?C2)
  (test (< (* ?C1 ?C2) 0))
  (test (neq ?fact1 ?fact2))
=>
  (retract ?fact1 ?fact2)
  (bind ?C3 (/ (+ ?C1 ?C2) (- 1 (min (abs ?C1) (abs ?C2)))))
  (assert (organism ?attribute ?value ?C3)))
```

28

CLIPS Session:

```
CLIPS> (load "cf_ornek.clp")
Defining defrule: start +j
Defining deffacts: initial-organism-facts
Defining defrule: combine-certainties-both-positive +j+j
Defining defrule: combine-certainties-both-negative +j+j
Defining defrule: combine-certainties-with-opposite-signs +j+j
TRUE
CLIPS> (reset)
CLIPS> (run)
CLIPS> (facts)
f-0 (initial-fact)
f-7 (patient is-a compromised-host 0.8)
f-8 (organism morpholgy rod 0.25)
f-11 (organism stain gramneg 0.58)
For a total of 4 facts.
```

29

Advantages/Disadvantages of Certainty Factors

Advantages:

- simple implementation
- reasonable modeling of human experts' belief
- successful applications for certain problem classes
- evidence relatively easy to gather
 - no statistical base required

Disadvantages:

- partially ad hoc approach
 - theoretical foundation through Dempster-Shafer theory was developed later
- combination of non-independent evidence unsatisfactory
- new knowledge may require changes in the certainty factors of existing knowledge
- certainty factors can become the opposite of conditional probabilities for certain cases
- not suitable for long inference chains

30