Lecture 5: Case-Based Reasoning and Its Relation with Fuzzy Systems

Ning Xiong

School of Innovation, Design, and Engineering
Mälardalen University, Sweden

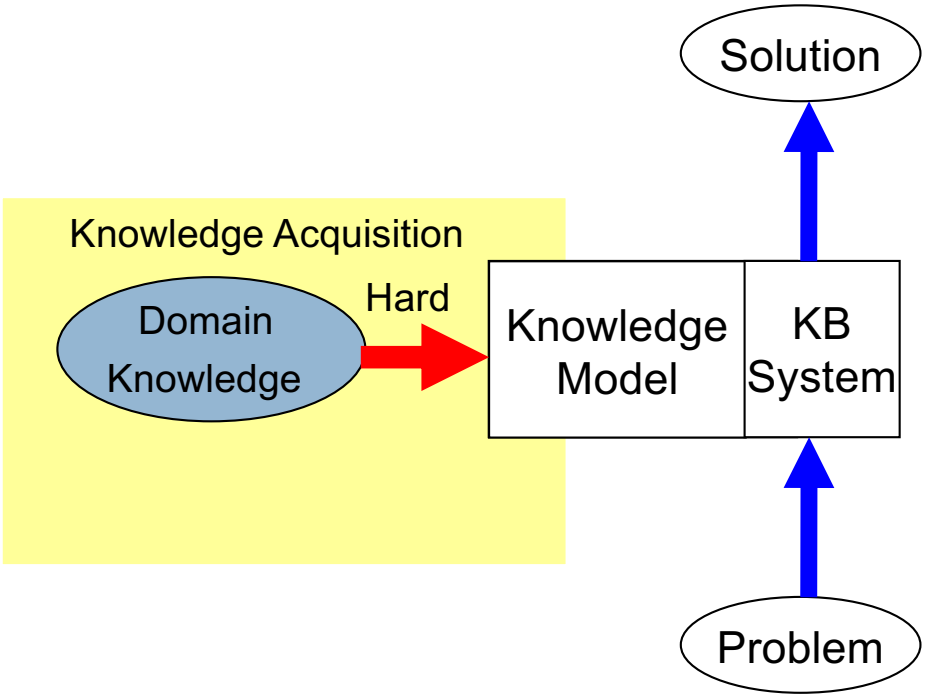
Agenda

- What is case-based reasoning (CBR) ?
- Practical techniques in CBR
- The relation of CBR with fuzzy systems

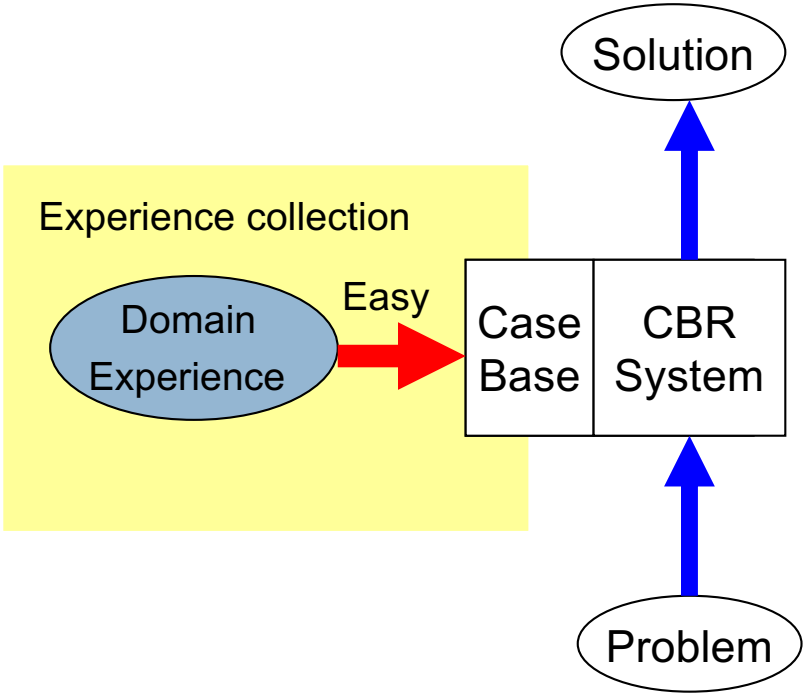
What is Case-Based Reasoning

What is Case-Based Reasoning (CBR)

Traditional Knowledge-Based systems



Case-Based Reasoning Systems

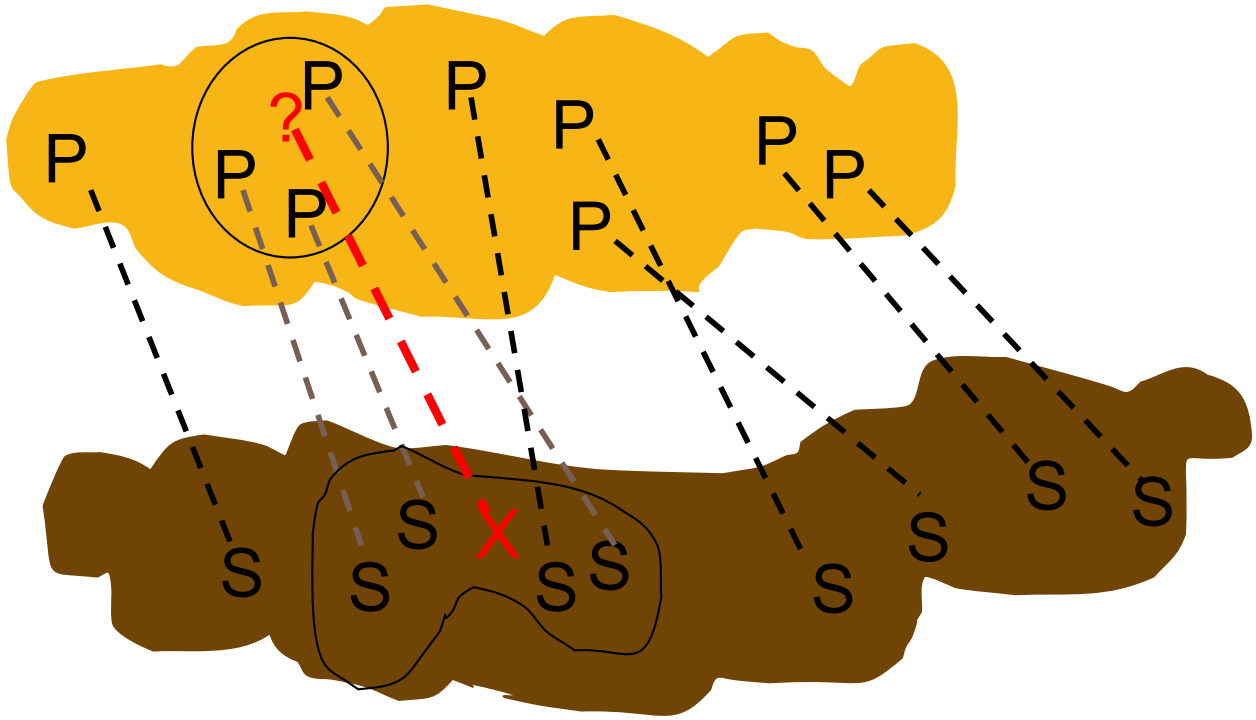


Humans often use available experiences in solving new problems

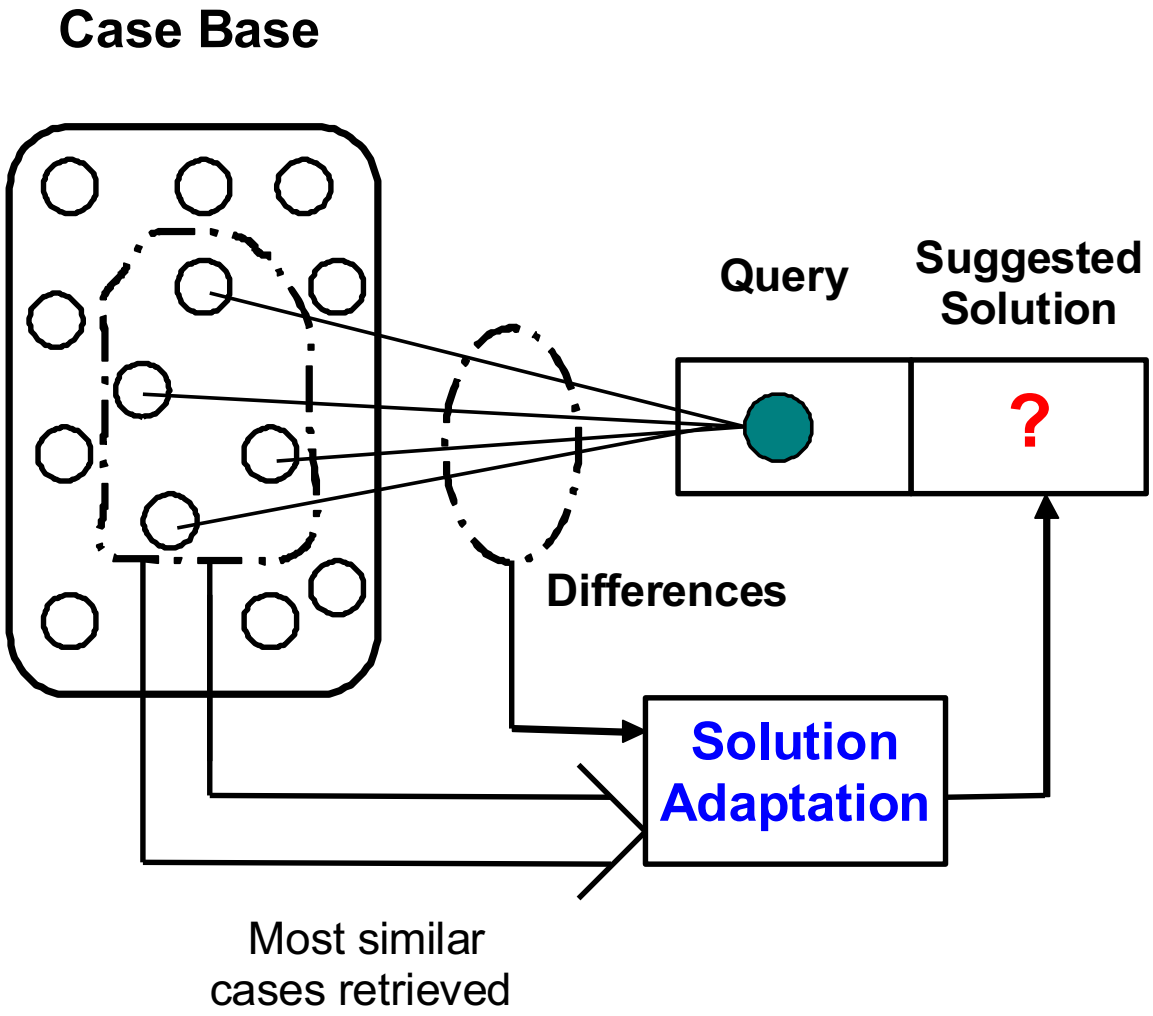
Problem: 999 x 9 = ?
Known case: 1000 x 9 = 9000
Modication: 999 x 9 = 9000 − 9

Fundamental Principle of CBR

Similar problems have similar solutions



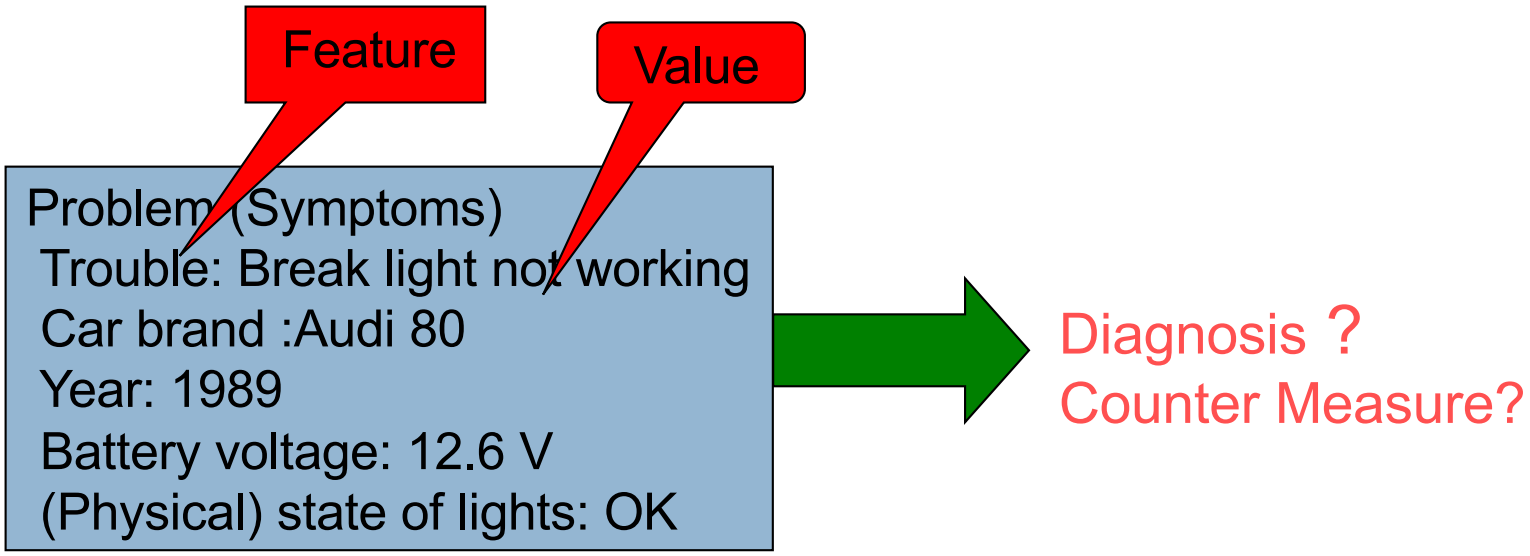
How is CBR Working



- A case in the case base contains a set of values of features and the associated solution
- A problem in query has only feature values

A Car Diagnosis Problem

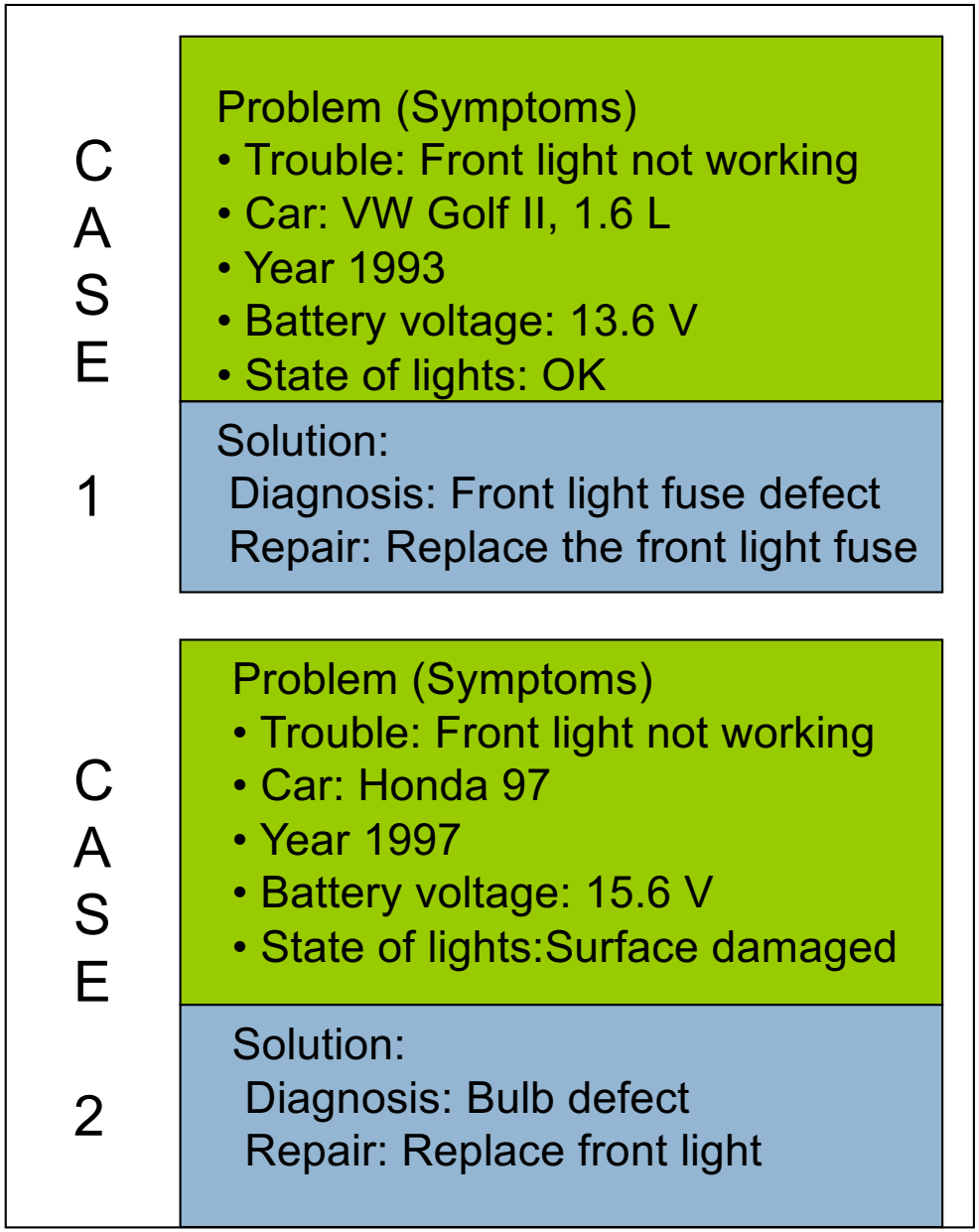
Current states of the car define a problem in query:



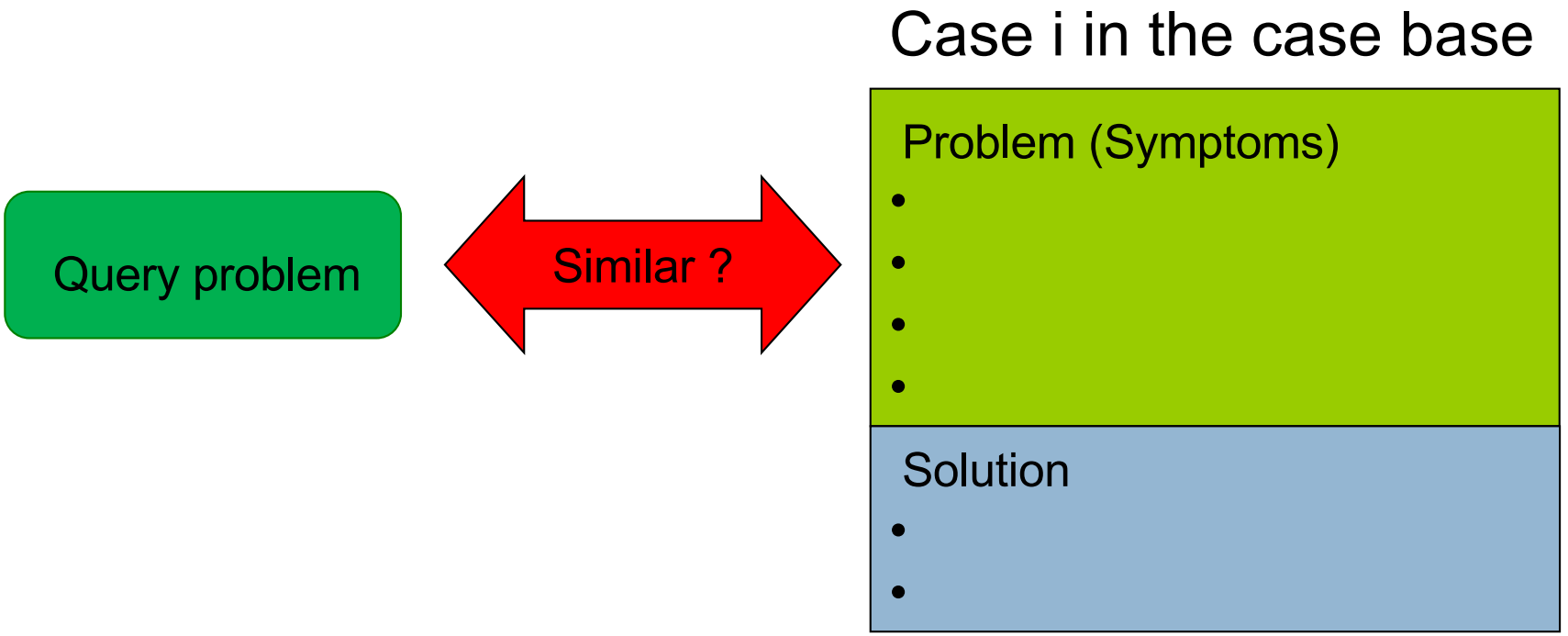
A query problem is a case without solution part

A Case Base with Two Cases

- Each case describes experience in one particular situation
- All cases are independent from each other



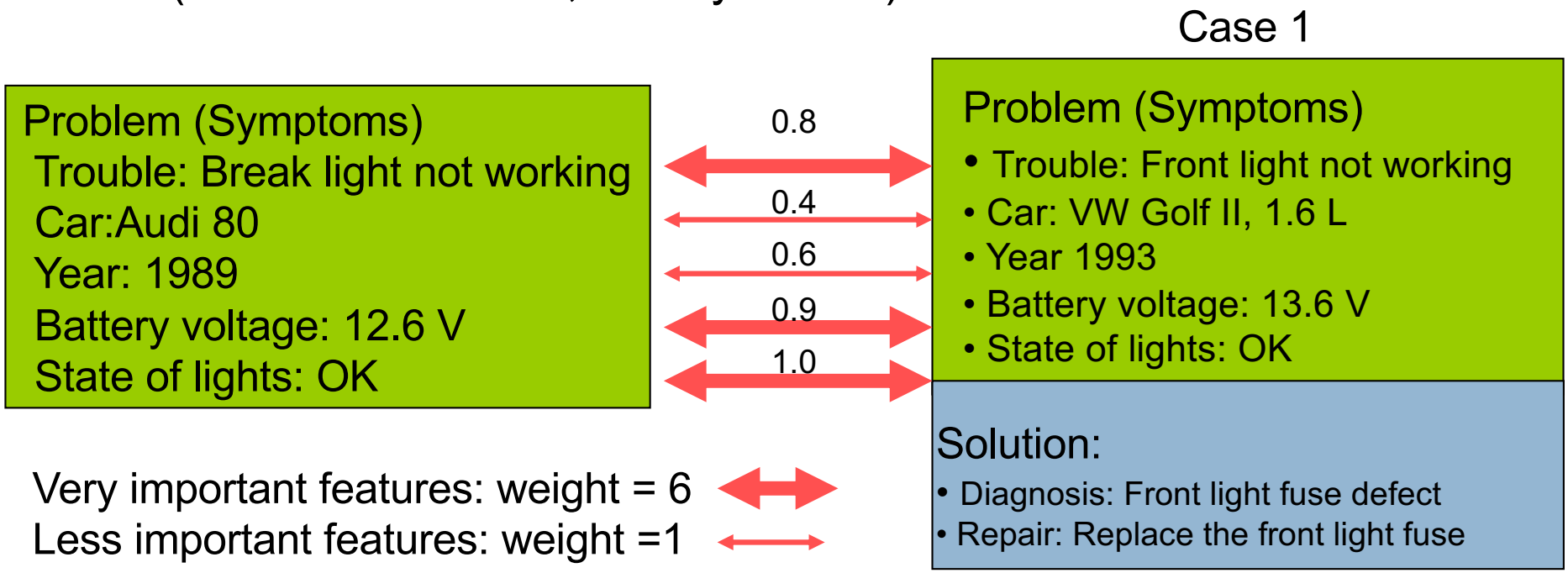
Compare between Query and Known cases



- Similarity is one of the most important concepts in case-based reasoning
- Similarity is assessed based on the difference on each feature
- But different features may have different importance

Similarity Computation

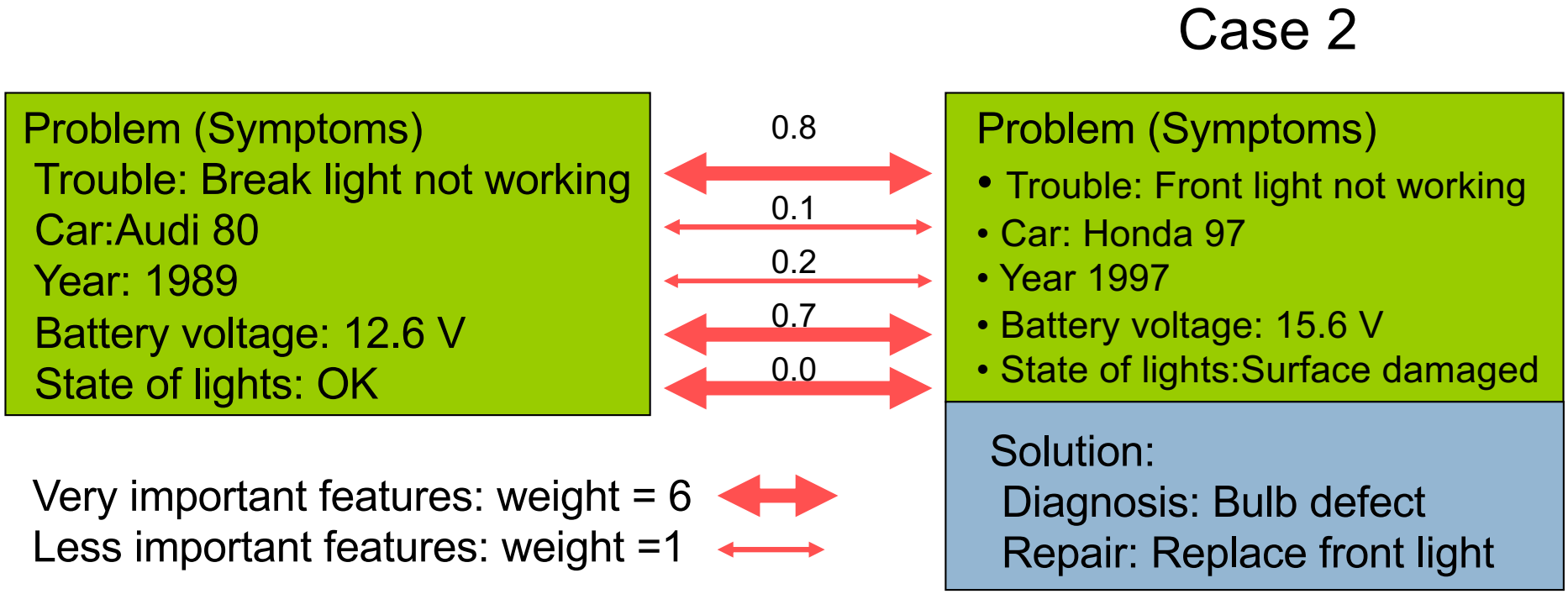
1. Assignment of local similarity degrees on features with a number between 0 and 1 (0: not similar at all; 1: very similar)



2. Global similarity calculated as a weighted average of local similaritiy degrees on features:

$$Sim(query, case\ \ 1) = \frac{6*0.8+1*0.4+1*0.6+6*0.9+6*1.0}{6+1+1+6+6} = 0.86$$

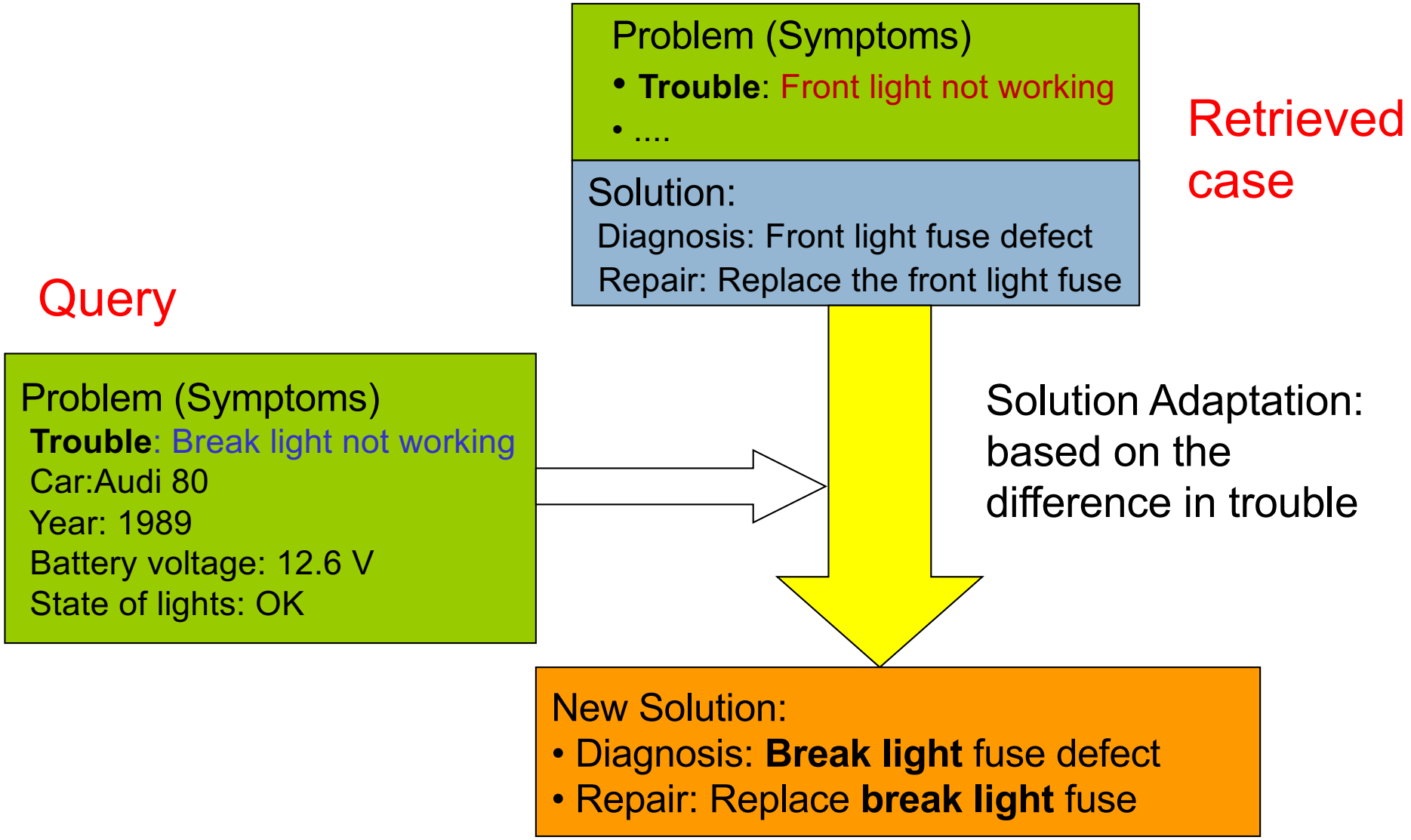
Compare Query Problem with Case 2



The case similarity calculated as a weighted average of local similaritiy degrees on features:

$$Sim(query, case\ \ 2) = \frac{6*0.8+1*0.1+1*0.2+6*0.7+6*0}{6+1+1+6+6} = 0.465$$

Case 1 Retrived for Adaptation



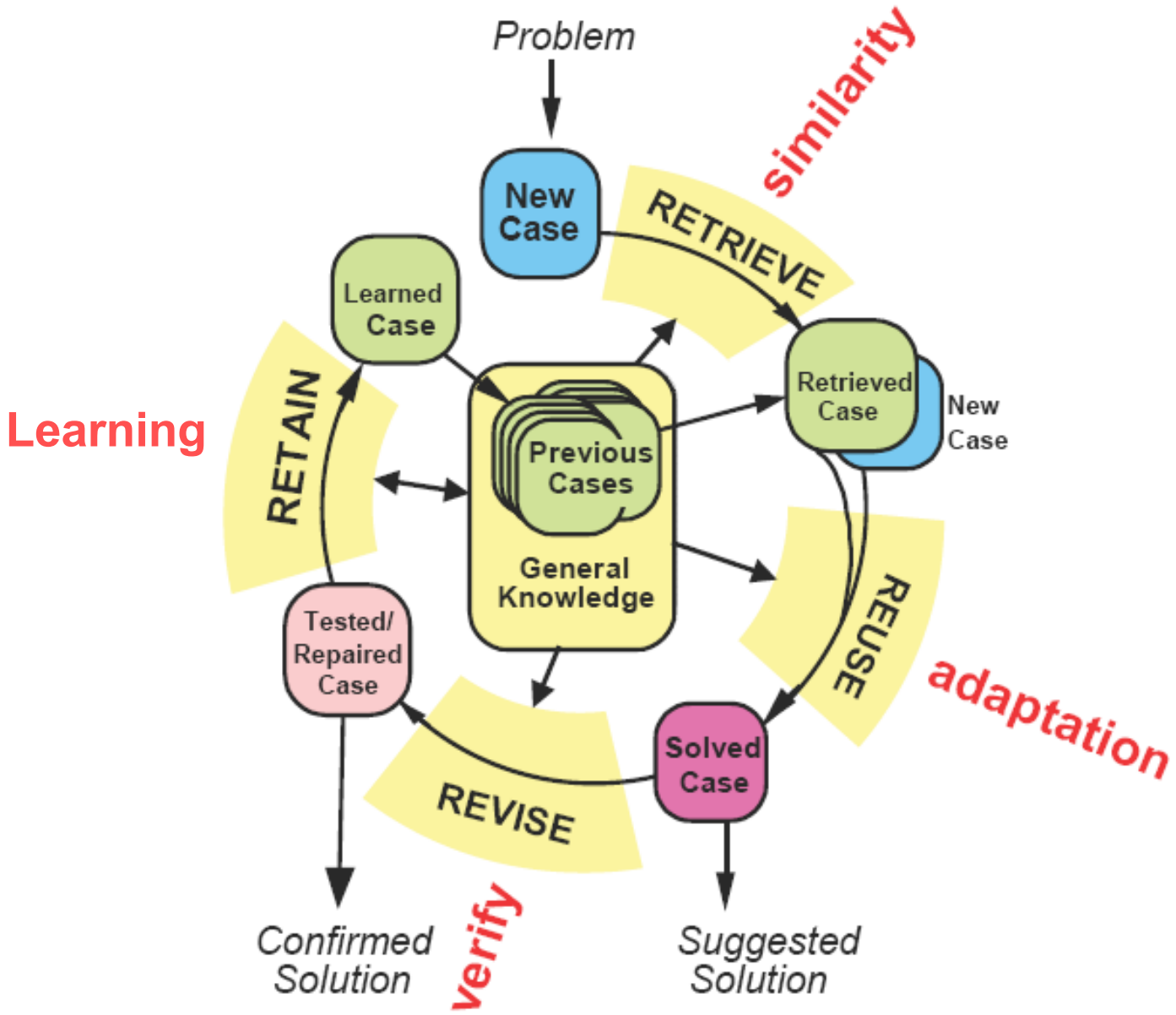
Store the New Experience

If the solution is correct, store the new case in the case base (retain of new experience)

Case 3

Problem (Symptoms)
Trouble: Break light not working Car brand :Audi 80 Year: 1989 Battery voltage: 12.6 V (Physical) state of lights: OK
Solution: • Diagnosis: Break light fuse defect • Repair: Replace break light fuse

CBR Cycle


Problem
New Case
similarity
RETRIEVE
Learned Case
Retrieved Case
New Case
Learning
RETAIN
Previous Cases
General Knowledge
REUSE
adaptation
Tested/ Repaired Case
Solved Case
REVISE
Confirmed Solution
verify
Suggested Solution

Advantages of CBR

Advantages:

- Domains not need to be completely understood
- Ease the knowledge acquisition bottleneck
- Simplify problem solving procedure, i. e., derivation from scratch is avoided
- Enable a sort of incremental learning (case retain)
- Increasing applications of CBR in many areas such as:

  fault diagnosis, scheduling, planning, pattern classification

Limitation:

- Difficulty in case adaptation

Practical Techniques in CBR

Similarity Metrics

Similarity metrics play a central role in CBR for retrieval of similar cases given a new problem (query case).

Usually similarity can be assessed by using one of the metrics as follows:

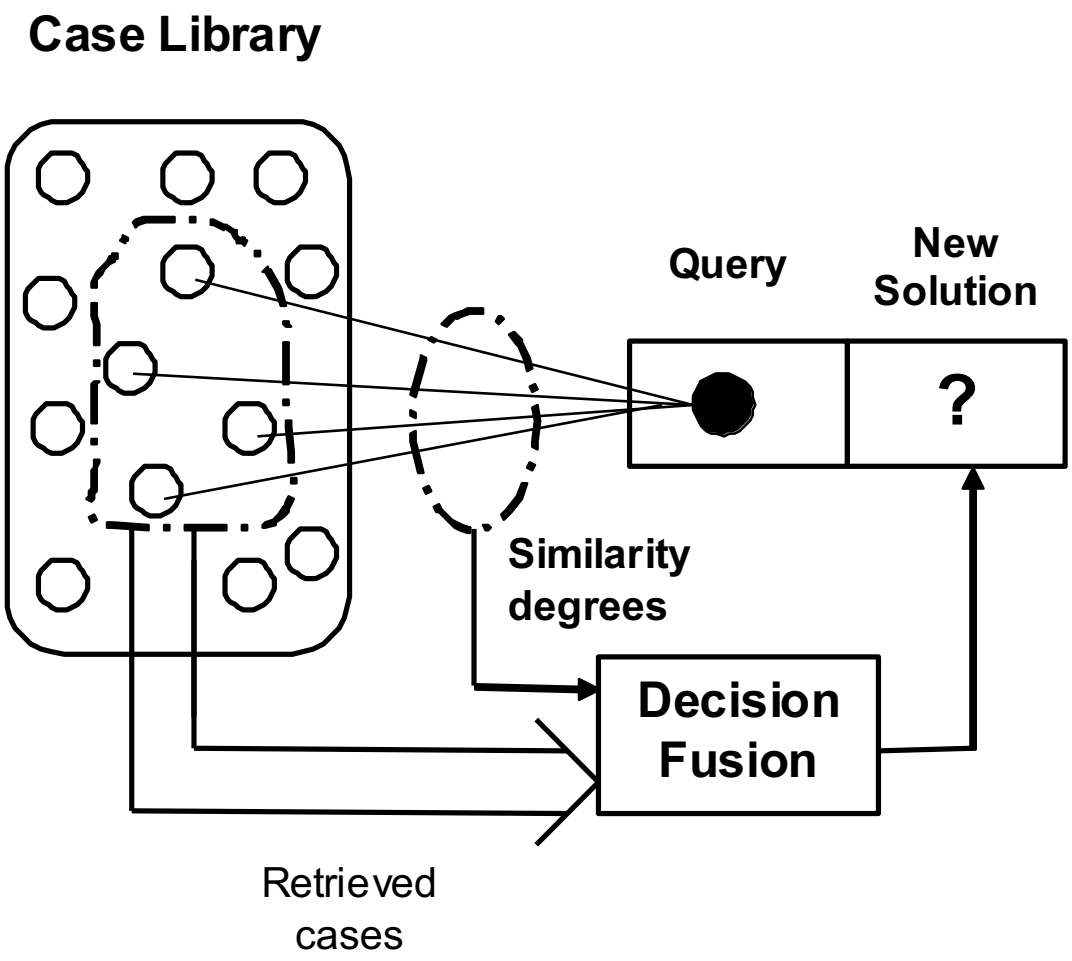
Weighted Euclidean distance: $DIST(X,Y) = \sqrt{\sum_{i=1\cdots n} w_i (x_i - y_i)^2}$

Weighted Manhattan distance: $DIST(X,Y) = \sum_{i=1\cdots n} w_i \left| x_i - y_i \right|$

Weighted average on local similarity values on attributes:

Weights reflect the importance of features

Case Reuse by Decision Fusion



Ways of Decision Fusion

Classification: a) majority class

b) Voting strength for class(class with maximum *VS*)

$$VS(B) = \sum_{C \in Retrieved} \begin{cases} Sim(C,Q), & if\ conseq(C) = B \\ 0, & otherwise \end{cases}$$

Numerical prediction:

$$y = \frac{\sum_{C_i \in Retrieved} y_i \cdot Sim(C_i, Q)}{\sum_{C_i \in Retrieved} Sim(C_i, Q)}$$

Relation between CBR and Fuzzy Systems

CBR and Fuzzy Reasoning

Case-Based Reasoning

- A memory of known cases
- Matching a query problem to cases; similarity as the measure
- No exact matching is required, but the degrees of similarity are extensively used
- **A case is a specific form of fuzzy rule; r**egarded as a fuzzy rule with all membership functions being singletons

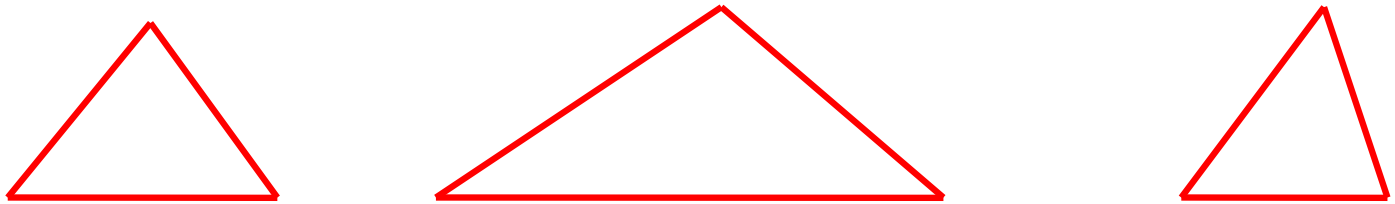
Fuzzy Rule-Based Reasoning

- A set of if-then rules: if A_i and B_i then C_i
- Matching a query problem to rules; firing strength as the measure
- No exact matching is required, but the strengths of firing are extensively used
- **A fuzzy rule can be considered as a generalzed case,** covering many concrete cases

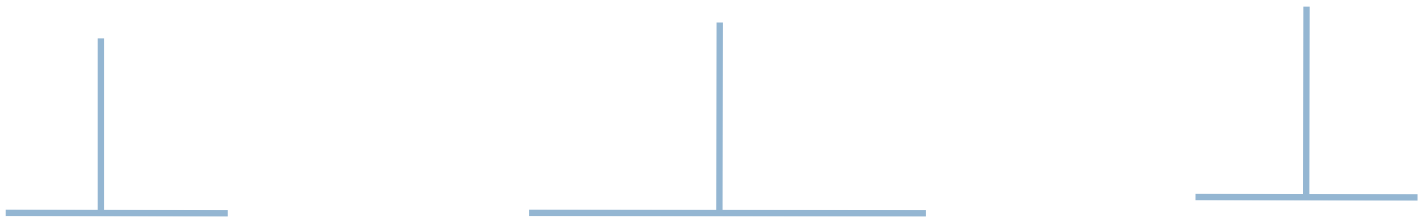
Cases and Fuzzy Rules

Fuzzy rule as generalized case:

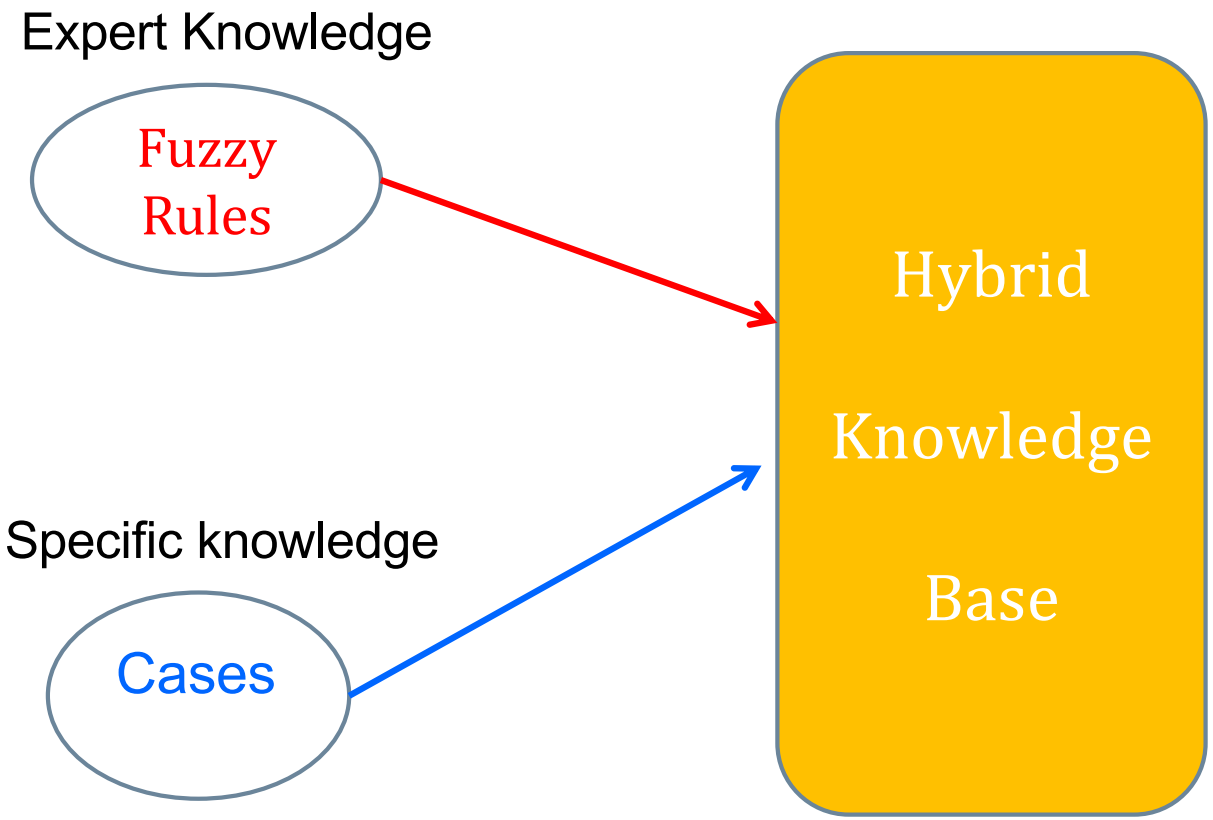
If $X_1=A_1$ and $X_2=A_2$ then $Y=C_1$



Case as special form of fuzzy rules:



Integrating Cases and Fuzzy Knowledge



Possibility for unified case-based and fuzzy rule based reasoning

CBR in Fuzzy View

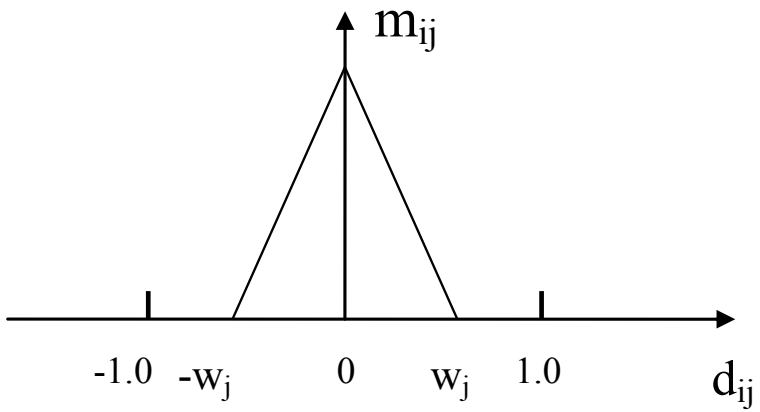
- The fundamental principle of CBR ”similar problems have similar solutions” can be formulated as fuzzy rule:

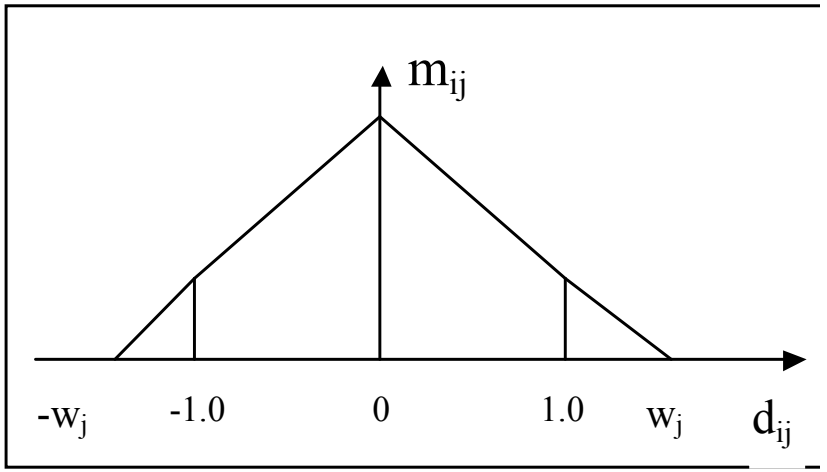
If problem A is similar to problem B,
then the solution of A is similar to that of B

- Define the concept ”similar” in fuzzy view as a fuzzy subset

Local Similarity

- The local similarity can be considered as a fuzzy subset on the feature difference, whose membership function can be defined as shown in the following figures:





- The parameter w_j reflects the importance of the feature
- The meaning of similarity for different features is different

Global Similarity

- The criterion for similarity between a library case C_i and query Q can be formulated with the following fuzzy rule:

  If (feature 1 of C_i is similar to that of Q) and …… and (feature *n* of C_i is similar to that of Q) then C_i is similar to Q

  Hence similarity degree between C_i and Q is equal to the firing strength of the rule:

$$Sim(C_i, Q) = \min(m_{i1}, m_{i2}, \quad \cdots \quad , m_{in})$$

- A new similarity measurement without feature weighting

- More flexible to exclude a remote case in the reasoning procedure