Case-Based Reasoning

6.871: Knowledge-Based Application Systems
Spring 2004
Lecture 17

What is Case-Based Reasoning (CBR)

Case-based reasoning is [...] remembering.
Leake, 1996

A case-based reasoner solves new problems by adapting solutions that were used to solve old problems.
Riesbeck & Schank, 1989

Case-based reasoning is a recent approach to problem-solving and learning [...].
Aamodt & Plaza, 1994

Case-based reasoning is both [...] the ways people use cases to solve problems and the ways we can make machines use them.
Kolodner, 1993

What is Case-Based Reasoning?

- A methodology to model human reasoning
- A methodology for building intelligent systems

- CBR:
  - Store previous experience (cases) in memory
  - Solve new problems by
    - Retrieving experience about <u>similar</u> situations
    - Reusing the experience in context of new situation: use all or part, or <u>adapt, test</u>
    - Storing new experience in memory, i.e. <u>learn</u>

Why Case-Based Reasoning?

- It's pervasive
  - Law, medicine, design, politics, common sense
- It's intuitive
  - Seems to match our experience
- It's powerful
  - *One or two order of magnitude* speedup
- It provides a natural means to learn from experience
  - An almost effortless side-effect of problem solving
- It can work in partially understood domains
  - When we don't have a good theory/model
- It provides a way to avoid mistakes
  - Can save additional time

So …

- Is it THE ANSWER?

- Isn't this just another name for frames?

A Simple Example:
Diagnosis of Car Faults

- Given: Symptoms
  e.g. engine doesn't start
  and measured values
  e.g. battery voltage = 6.3V
- Goal: Find cause for fault
  e.g. dead battery
  and repair strategy
  e.g. charge battery

Example Cases

Case 1

Problem & Features
- Problem: Front light not working
- Car: VW Golf, 2.0L
- Year: 1999
- Battery voltage: 13.6V
- State of lights: OK
- State of light switch: OK

Solution
- Diagnosis: Front light fuse defect
- Repair: Replace front light fuse

Case 2

Problem & Features
- Problem: Front light not working
- Car: Passat
- Year: 2000
- Battery voltage: 12.6V
- State of lights: surface damaged
- State of light switch: OK

Solution
- Diagnosis: Bulb defect
- Repair: Replace front light

6.871 - Lecture 17   8

New Problem

- Observations define a new problem
- Not all feature values may be known
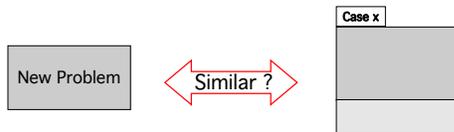- New problem = case without solution

Problem & Features
- Problem: Brake light not working
- Car: Passat V6
- Year: 2002
- Battery voltage: 12.9V
- State of lights: OK
- State of light switch: ?

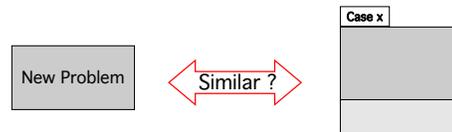6.871 - Lecture 17   9

Find Similar Case

New Problem   ⟷ Similar ?   **Case x**

6.871 - Lecture 17   10

Find Similar Case

New Problem   ⟷ Similar ?   **Case x**
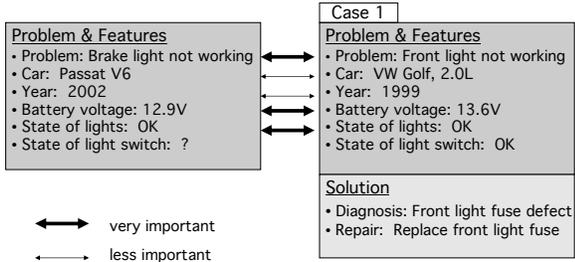
- Compare similarity of each feature
- But some features may be more important
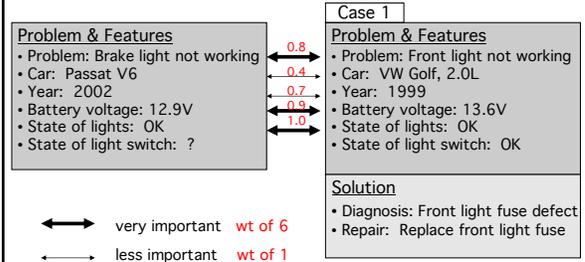
6.871 - Lecture 17   11

Compare with Case 1

Problem & Features
- Problem: Brake light not working
- Car: Passat V6
- Year: 2002
- Battery voltage: 12.9V
- State of lights: OK
- State of light switch: ?

Case 1

Problem & Features
- Problem: Front light not working
- Car: VW Golf, 2.0L
- Year: 1999
- Battery voltage: 13.6V
- State of lights: OK
- State of light switch: OK

Solution
- Diagnosis: Front light fuse defect
- Repair: Replace front light fuse

⟷ very important

→ less important

6.871 - Lecture 17   12

Compare with Case 1

Problem & Features
- Problem: Brake light not working
- Car: Passat V6
- Year: 2002
- Battery voltage: 12.9V
- State of lights: OK
- State of light switch: ?

Case 1

Problem & Features
- Problem: Front light not working
- Car: VW Golf, 2.0L
- Year: 1999
- Battery voltage: 13.6V
- State of lights: OK
- State of light switch: OK

Solution
- Diagnosis: Front light fuse defect
- Repair: Replace front light fuse

0.8
0.4
0.7
0.9
1.0

⟷ very important   wt of 6

→ less important   wt of 1

Similarity by wted avg = 1/20 (6*0.8 + 1*0.4 + 1*0.7 + 6*0.9 + 6*1.0) = 0.87

6.871 - Lecture 17   13

Compare with Case 2

Problem & Features
- Problem: Brake light not working
- Car: Passat V6
- Year: 2002
- Battery voltage: 12.9V
- State of lights: OK
- State of light switch: ?

Case 2
Problem & Features
- Problem: Front light not working
- Car: Passat
- Year: 2000
- Battery voltage: 12.6V
- State of lights: surface damaged
- State of light switch: OK

0.8
0.8
0.8
0.9
0.0

Solution
- Diagnosis: Bulb defect
- Repair: Replace front light

⟷ very important   wt of 6

← → less important   wt of 1

Similarity by wted avg = 1/20 (6*0.8 + 1*0.8 + 1*0.8 + 6*0.9 + 6*0.0) = 0.59

Reuse Case 1

Case 1
Problem & Features
- Problem: Front light not working
- ...

Solution
- Diagnosis: Front light fuse defect
- Repair: Replace front light fuse

Problem & Features
- Problem: Brake light not working
- ...

Adapt

New Solution
- Diagnosis: Brake light fuse defect
- Repair: Replace Brake light fuse

Store New Case

Case 3
Problem & Features
- Problem: Brake light not working
- Car: Passat V6
- Year: 2002
- Battery voltage: 12.9V
- State of lights: OK
- State of light switch: OK

Solution
- Diagnosis: Brake light fuse defect
- Repair: Replace brake light
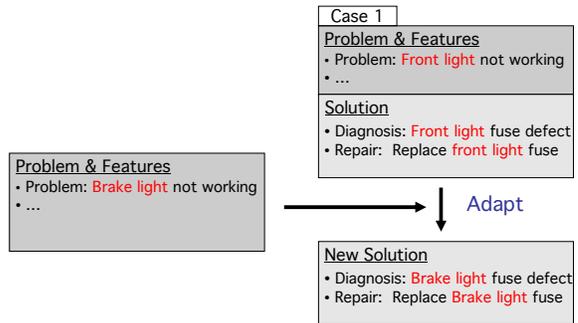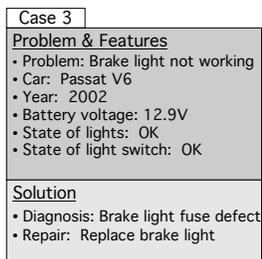
Case-Based Diagnosis

- A case represents one diagnostic situation:
  - symptoms
  - failure and cause
  - feature values
  - repair strategies
  - outcome: implicit assumption failure fixed
- Problem solving:
  - store collection of cases
  - find similar case, adapt if necessary, suggest repair strategies
- Learning:
  - observe outcome, store new case

Case-Based Reasoning

- Retrieve
- Reuse: adapt/repair
- Store/Learn

Case-Based Reasoning

- Retrieve
  - How?
  - Selecting indexes
    - Determine case utility/lessons
    - Describe circumstances where it will be useful
    - Represent those circumstances (features)
    - Generalize

Case-Based Reasoning

- Retrieval: Indexing
  - "Look at the tasks a case might be used for and choose as indexes those sets of its features that describe when it can be useful for each task."
  - "The indexing vocabulary must capture those dimensions of the domain that need to be captured for useful reminding. The level of detail required in the symbols used for representation depends on how specifically-similar cases must be to provide credible advice."

Case-Based Reasoning

- Retrieval: What to focus on
  - "...matching algorithms must be able to distinguish which indexed features to focus on at any time.

    For this reason, input to retrieval algorithms includes both a description of the new situation and also an indication of what the reasoner will use the case for.... Matching and ranking procedures use this description to determine which features of a case are the most important to focus on in judging similarity."

Case-Based Reasoning

- Reuse: adapt/repair
  - Adaptation via
    - Substitution
    - Parameter adjustment (via specialized heuristics, eg Judge)
    - Local search (replacing fruits in a recipe)
    - Special purpose adaptation and repair
    - Model-based
    - ....

Case-Based Reasoning

- Store/Learn
  - By accumulating cases
  - By "assignment and unassignment of indexes"

Case-Based Reasoning

- AKA frames?

Examples
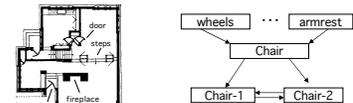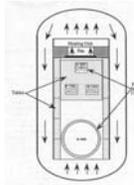
Quarterly_earning:	0.15
Long_term_debt:	20%
Age_of:	10
Industry-type:	Chemistry
Investment_decision: invest	

Vanilla Souffle	Mix flour, sugar, salt. Mix in milk.
2 tsp vanilla	Simmer for 5 minutes.
1/2 c flour	Whip egg yolks.
1/4 c sugar	Add butter and yolks
1/4 t salt	to mixture.
1/2 c milk	Cool mixture.
1/4 c butter	Whip egg whites.
5 egg yolks	Add vanilla and egg
5 egg whites	whites to mixture.
	Pour mixture into 9" dish.
	Bake for 10 min at 400°.

25

Casey

- Case-based medical diagnosis via a causal model of heart disease
- Retrieve
  - Indexing: distinguish significant indexes when storing; score matches
- Reuse: adapt/repair
  - Insignificant differences: not involved in causal expln
  - Repairable: can be fit into the causal model
- Store/Learn
  - Index by states directly linked to findings
  - Generalizes over features

Similarity

- Static at insertion or dynamic at retrieval
- Method for computing depends on representation, e.g.
  - weighted average
  - (sub)graph isomorphism
  - geometric routines
  - logical inference

Retrieval

- Can use k-nearest-neighbors
- Can organize cases, e.g.:
  - decision trees
  - discrimination nets

Adaptation

- Manual/interactive adaptation by user
- Automatic
  - Transformational analogy
    = transform solution via operators or rules
  - Derivational analogy
    = replay problem solving trace to derive new solution

Verification

- Observation in real world

- Simulation

- Criteria:
  - correctness of solution
  - quality of solution
  - other, e.g. user preferences

Learning

- What:
  - new experience
  - improved similarity metrics
  - improved adaptation techniques
  - improved organization of cases
- How:
  - storing new cases
  - deleting old cases

Advantages of CBR

- Can use when have "weak" domain theory
- Reduces knowledge acquisition effort
- Can propose solutions from incomplete problem statement
- Improves over time as case base grows
- High user acceptance

Disadvantages of CBR

- Cases may not cover domain well
- Most appropriate cases may not be retrieved
- Still need similarity, adaptation, and verification knowledge
- In the absence of a good theory, the indexing, retrieval, learning can be ad hoc.

The CBR Glasses

- Problem solving based on past experience
- Similar problem implies similar solution
- Experience stored as cases
- Process: retrieve, reuse, verify, store
  - retrieval: similarity
  - reuse: adaptation
  - verification: observation, simulation
  - storage: learning