Case-Based Reasoning

*gentle intro*

Dr. Ian Watson
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  - simple
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precedent [pres-e-d(a)nt] n.
previous case or occurrence taken as guidance. *Collins Dictionary*
Precedents

- we are all comfortable with the concept of precedent
- precedents inform many of our daily decisions
- they are the basis of our legal system
Precedents
would you rather bet on, the Black Caps or India?
Precedents

- would you rather bet on, the Black Caps or India?
- you expect a product to cost the same today as it did yesterday
Precedents

- Would you rather bet on, the Black Caps or India?
- You expect a product to cost the same today as it did yesterday.
- Companies make thousands of decisions a day.
Precedents

- would you rather bet on, the Black Caps or India?
- you expect a product to cost the same today as it did yesterday
- companies make thousands of decisions a day
- successful decisions can be used as precedents
Precedents - CBR

- Case-Based Reasoning (CBR)
- uses precedents (prior decisions or actions) to inform current decisions
- CBR is
  - intuitive
  - relatively simple to implement
  - transparent
  - and it learns
Decision Support
Decision Support

- System developers have problems
  - The knowledge elicitation bottleneck
  - Decision support is dynamic
  - Systems require constant maintenance
  - Systems must be accepted
  - Advice must be justified
Decision Support

- system developers have problems
  - the knowledge elicitation bottleneck
  - decision support is dynamic
  - systems require constant maintenance
  - systems must be accepted
  - advice must be justified

- CBR addresses each of these problems
What is CBR?
What is CBR?

- A case-based reasoner solves new problems by using or adapting solutions that were used to solve old problems.
What is CBR?

- A case-based reasoner solves new problems by using or adapting solutions that were used to solve old problems.
- Offers a reasoning paradigm that is similar to the way many people routinely solve problems.
What Is CBR?
What Is CBR?

- What is 12 x 12?
What Is CBR?

- What is $12 \times 12$?
- 144
What Is CBR?

- What is 12 x 12?
- 144
- What is 12 x 13?
What Is CBR?

- What is $12 \times 12$?
- $144$
- What is $12 \times 13$?
- *near* $12 \times 12$
What Is CBR?

- What is $12 \times 12$?
- $144$
- What is $12 \times 13$?
- *near* $12 \times 12$
- $(12 \times 12) + 12$
What Is CBR?

- What is $12 \times 12$?
- $144$
- What is $12 \times 13$?
- *near* $12 \times 12$
- $(12 \times 12) + 12$
- $156$
What is a Case?
What is a Case?

- several features describing a problem
What is a Case?

- several features describing a problem
- plus an outcome or a solution
What is a Case?

- several features describing a problem
- plus an outcome or a solution
- cases can be very rich
  - text, numbers, symbols, plans, multimedia,
What is a Case?

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- plus an outcome or a solution
- cases can be very rich
  - text, numbers, symbols, plans, multimedia,
- cases are not distilled knowledge
- cases are records of real events
- and are excellent for justifying decisions
The Case-Based Cycle
The Case-Based Cycle

Problem
The Case-Based Cycle

Problem → RETRIEVE → CASE-BASE → Similar Cases

PRIOR CASES
The Case-Based Cycle

1. **Problem**
2. **Retrieval**
   - RETRIEVE
   - Similar Cases
3. **Reuse**
   - CASE-BASE
   - PRIOR CASES
4. **Solution**
The Case-Based Cycle

Problem → RETRIEVE → Similar Cases → CASE-BASE → REVISE → Solution
The Case-Based Cycle

- **Problem**
- **RETRIEVE**
- **Case-Base**
- **REVISE**
- **Similar Cases**
- **REUSE**
- **Solution**

The Case-Based Cycle consists of the following steps:

1. **Problem**: Identify the current problem or issue.
2. **RETRIEVE**: Search for similar cases in the Case-Base.
3. **Case-Base**: Retrieve relevant prior cases.
4. **REVISE**: Adapt the solutions from the retrieved cases to fit the current problem.
5. **REUSE**: Implement the revised solution, possibly using it in a similar context.
6. **Solution**: Finalize the solution, ready for application.
7. **RETAIN**: Store the solution as part of the Case-Base for future reference.

This cycle allows for the reuse of previous solutions, enhancing efficiency and effectiveness in problem-solving.
CBR is Intuitive

- this is how we routinely make decisions
- experts rely on their experience
- novices use rules and first principles
- consequently CBR is
  - easy to sell to management
  - easy to sell to users
CBR is Simple

- simple to implement
- you don’t need a Ph.D. in maths, cs, logic or astro-physics
- all you need are precedents
- and simple software
How Does CBR Work?
How Does CBR Work?

- imagine a decision with two factors that influence it
How Does CBR Work?

- imagine a decision with two factors that influence it
- should you grant a person a loan?
  1. net monthly income
  2. monthly loan repayment
How Does CBR Work?

- these factors can be used as axes for a graph

- net monthly income
How Does CBR Work?

- A previous loan can be plotted against these axes.

Axes:
- Monthly loan repayment
- Net monthly income
How Does CBR Work?

- and a second loan
How Does CBR Work?

- and more loans
How Does CBR Work?

and even more loans
past cases (loans) will naturally tend to form clusters
How Does CBR Work?

- past cases (loans) may tend to form clusters
How Does CBR Work?

- past cases (loans) may tend to form clusters

Diagram:
- Good loans
- Bad loans

Axes:
- Monthly income
- Net monthly income
How Does CBR Work?

- a new loan prospect can be plotted on the graph

- net monthly income

- monthly income
How Does CBR Work?

- A new loan prospect can be plotted on the graph.
How Does CBR Work?

and the distance to its nearest neighbours calculated

each monthly

net monthly income

new case
How Does CBR Work?

- and the distance to its nearest neighbours calculated
How Does CBR Work?

- and the distance to its nearest neighbours calculated
How Does CBR Work?

• the best matching past case is the closest
How Does CBR Work?

- the best matching past case is the closest
How Does CBR Work?

- this suggests a precedent
How Does CBR Work?

- this suggests a precedent
- the loan will be successful
How Does CBR Work?

- over time the prediction can be validated

![Graph showing net monthly income and monthly loan repayment over time.](image-url)
How Does CBR Work?

- over time the prediction can be validated

- it was a good loan
How Does CBR Work?

- the system is learning to differentiate good and bad loans better

<table>
<thead>
<tr>
<th>net monthly income</th>
<th>net monthly income</th>
</tr>
</thead>
<tbody>
<tr>
<td>monthly</td>
<td>monthly</td>
</tr>
</tbody>
</table>

[Diagram showing data points and trend lines]
How Does CBR Work?

- as more cases are acquired its performance improves
How Does CBR Work?
How Does CBR Work?

- in real life the problem space is $N$ dimensional
How Does CBR Work?

- in real life the problem space is $N$ dimensional
- feature vectors can be weighted to reflect their relative importance
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- new features can be added if they become relevant
How Does CBR Work?

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- feature vectors can be weighted to reflect their relative importance
- new features can be added if they become relevant
- tolerant of noise & missing data
How Does CBR Work?

- In real life, the problem space is $N$ dimensional.
- Feature vectors can be weighted to reflect their relative importance.
- New features can be added if they become relevant.
- Tolerant of noise & missing data.
- Termed Nearest Neighbour Retrieval.
CBR is Transparent

- precedent is an accepted method for justifying a decision
- nearest neighbour retrieves the best matching past cases
- the process is transparent
- i.e., easily understood by users
- this increases acceptance
CBR is Transparent

- rule-based systems justify decisions by showing a rule trace
- decision grant loan because
  rule 24 -> rule 61 -> rule 43 -> rule 202
- rule traces can be confusing to users
CBR is Transparent

• neural nets and genetic algorithms cannot justify their decisions
CBR is Transparent

- neural nets and genetic algorithms cannot justify their decisions
- inputs disappear into a black box
CBR is Transparent

- neural nets and genetic algorithms cannot justify their decisions
- and reappear without justification
CBR is Transparent

- neural nets and genetic algorithms cannot justify their decisions
- users have to *trust* the computer is always correct
CBR Systems Learn

- Decision making is dynamic
- CBR systems learn by acquiring new cases
  - No addition of new rules
  - No retraining of neural networks
  - No reevolving new populations with new genomes
  - No reinduction of rules from data
Who Uses CBR?

- American Express - credit card risk assessment
- Microsoft – help desks
- Barclaycard - fraud watch
- General Electric – train diagnostics, plastic fabrication
- British Airways – plane maintenance
- Daimler Chrysler – software support
- Analog – component selection
- NASA – space shuttle support
- Swiss Bank - investment management
- Deloitte Touche - fraud assessment
Lockheed
PROBLEM - how to optimise the loading of an autoclave for curing composite materials
**Lockheed**

- **PROBLEM** - how to optimise the loading of an autoclave for curing composite materials
- different materials need different heating & cooling procedures
PROBLEM - how to optimise the loading of an autoclave for curing composite materials

different materials need different heating & cooling procedures

materials interact with each other in the autoclave
PROBLEM - how to optimise the loading of an autoclave for curing composite materials

different materials need different heating & cooling procedures

materials interact with each other in the autoclave

mistakes are VERY costly
Lockheed
2 experienced operators relied on plans of previously successful layouts
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New layouts were adapted from old
2 experienced operators relied on plans of previously successful layouts

- New layouts were adapted from old
- If successful they were added to a library
2 experienced operators relied on plans of previously successful layouts.

New layouts were adapted from old.

If successful they were added to a library.

They wanted to develop a decision support tool to assist experts and to retain expertise as a corporate asset.
Lockheed
Lockheed

- Lockheed had **NO** model of the autoclave
Lockheed

- Lockheed had **NO** model of the autoclave
- the manufacturers could not provide one
Lockheed

- Lockheed had **NO** model of the autoclave
- the manufacturers could not provide one
- layouts did not repeat
Lockheed

- Lockheed had **NO** model of the autoclave
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- materials were constantly changing
Lockheed had **NO** model of the autoclave

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Lockheed

- Lockheed had **NO** model of the autoclave
- the manufacturers could not provide one
- layouts did not repeat
- materials were constantly changing
- designs constantly change
- elements interact
Lockheed

- their system was implemented in 1990
- CLAVIER started with 20 successful layouts
- CLAVIER now has hundreds of successful layouts
- it retrieves a successful layout or adapts one 90% of the time
- acts as a corporate memory
The Case for CBR
The Case for CBR

- CBR is intuitive - it’s how we work
The Case for CBR

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- no knowledge elicitation to create rules or methods
The Case for CBR

- CBR is intuitive - it’s how we work
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- this makes development easier
The Case for CBR

- CBR is intuitive - it’s how we work
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- systems *learn* by acquiring new cases through use
The Case for CBR

- CBR is intuitive - it’s how we work
- no knowledge elicitation to create rules or methods
- this makes development easier
- systems *learn* by acquiring new cases through use
- this makes maintenance easy
The Case for CBR

- CBR is intuitive - it’s how we work
- no knowledge elicitation to create rules or methods
- this makes development easier
- systems *learn* by acquiring new cases through use
- this makes maintenance easy
- justification through precedent
The Case for CBR
The Case for CBR

- CBR is easy to understand
The Case for CBR

- CBR is easy to understand
- easy to use
The Case for CBR

- CBR is easy to understand
- easy to use
- and easy to sell to management and users
The Case for CBR

- CBR is easy to understand
- easy to use
- and easy to sell to management and users
- this increases the success of CBR systems
When to Apply CBR?
When to Apply CBR?

- when a domain model is difficult or impossible to elicit
When to Apply CBR?

- when a domain model is difficult or impossible to elicit
- when the system will require constant maintenance
When to Apply CBR?

- when a domain model is difficult or impossible to elicit
- when the system will require constant maintenance
- when records of previously successful solutions exist
When to Apply CBR?

- when a domain model is difficult or impossible to elicit
- when the system will require constant maintenance
- when records of previously successful solutions exist
- or when experts can design prototypical cases
AI-CBR
www.ai-cbr.org

• an Internet service for the CBR community
• an electronic mailing list with over 700 members (academics & industry)
• an Internet site with information on CBR research, places, people, papers, conferences, and much much more....
• FREE