Exploiting Knowledge by Means of of "Cases"

- **Case-based problem solving**
  Last time the light failed I replaced the bulb
- **Supervised learning of concepts**
  This is a positive example for a market where one should expand business
  In this situation one should not expand business
- **Unsupervised discovery of conceptual relations**
  People who buy beer, often also buy chips

"Case-based Reasoning" (CBR) is the discipline in Computer Science dealing with such problems.

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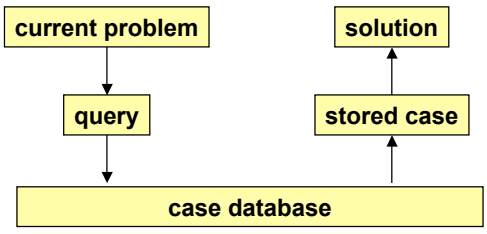
Case-based Problem Solving

Solving problems with the help of experiences stored as a case database.



Used by humans for almost all kinds of problem solving:

- **Diagnosis**
- **Design and Construction**
- **Planning**
- **Prediction**
- **Explanation**

How can this work?
Heraklit: Παντα ρει

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Example of Case-based Problem Solving

Problem:

Problem	
Diagnosis:	Influenza
Age:	12
Gender:	Male
Solution	
Medicine:	?
Dose:	?

case selection
+
adaptation

Stored cases:

Problem	
Diagnosis:	Influenza
Age:	32
Gender:	Female
Solution	
Medicine:	Aspirin
Dose:	2 pills per day

Problem	
Diagnosis:	Cold
Age:	12
Gender:	Male
Solution	
Medicine:	Orange Juice
Dose:	2 glasses per day

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Case-based Problem Solving as Pattern-directed Retrieval

Problem	
Diagnosis:	Influenza
Age:	12
Gender:	Male
Solution	
Medicine:	?
Dose:	?

Problem	
Diagnosis:	Influenza
Age:	32
Gender:	Female
Solution	
Medicine:	Aspirin
Dose:	2 pills per day

Problem	
Diagnosis:	Cold
Age:	12
Gender:	Male
Solution	
Medicine:	Orange Juice
Dose:	2 glasses per day

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Retrieval of relevant cases using a similarity measure Sim(x, y), e.g.:

Diagnosis		
Influenza	Cold	0.8
Influenza	Malaria	0.2
Influenza	Typhus	0.3
•		
•		
•		

Age	
0 ≤ age difference < 2	1.0
2 ≤ age difference < 5	0.9
5 ≤ age difference < 10	0.8
•	
•	
•	

Gender	
Same	1.0
Different	0.0

$$Sim(\underline{x}, \underline{y}) = w_{Diagnosis} * Sim_{Diagnosis}(x_1, y_1) + w_{Age} * Sim_{Age}(x_2, y_2) + w_{Gender} * Sim_{Gender}(x_3, y_3)$$

Weights w must be determined for each feature - how?

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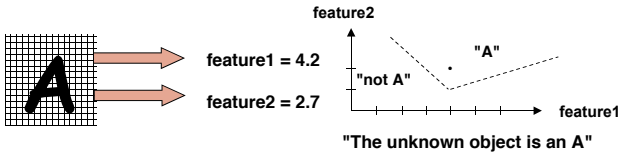
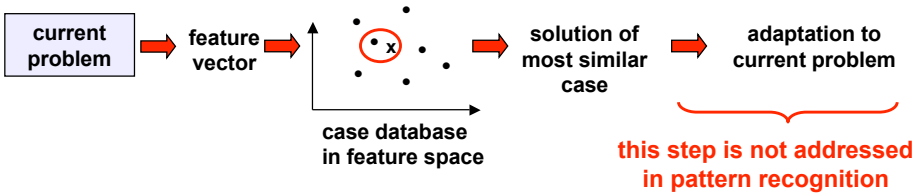
Comparison to Pattern Recognition

Pattern Recognition assigns objects (represented by feature vectors) to classes.

A typical pattern recognition problem:



Case-based reasoning can use a minimal-distance classifier to identify relevant problems in the case database:



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Case-based Problem Solving as Logical Inference (1)

Case-based reasoning = generalization + deduction

Generalization

Problem	
Diagnosis:	Influenza
Age:	32
Gender:	female
Solution	
Medicine:	Aspirin
Dose:	2 pills per day

⇒

Problem	
Diagnosis:	Influenza
Age:	> 18
Gender:	Male, Female
Solution	
Medicine:	Aspirin
Dose:	2 pills per day

Formalized domain knowledge

Problem	
Diagnosis:	Virus
Age:	> 18
Solution	
Dose:	x

implies

Problem	
Diagnosis:	Virus
Age:	< 18
Solution	
Dose:	x/2

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Case-based Problem Solving as Logical Inference (2)

Deduction

Problem	
Diagnosis:	Influenza
Age:	> 18
Gender:	Male, Female
Solution	
Medicine:	Aspirin
Dose:	2 pills per day

Problem	
Diagnosis:	Virus
Age:	< 18
Solution	
Dose:	x/2

implies

Problem	
Diagnosis:	Virus
Age:	> 18
Solution	
Dose:	x

Problem	
Diagnosis:	Influenza
Age:	12
Gender:	Male
Solution	
Medicine:	Aspirin
Dose:	1 pill per day

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Generalization of Cases (1)

1. Abstraction from irrelevant features

Problem	
Failure:	engine stop
Car Type:	VW Polo
Colour:	green
Fuel gauge:	empty
Solution	
Action:	Fill up fuel

Problem	
Failure:	engine stop
Car Type:	VW Polo
Fuel gauge:	empty
Solution	
Action:	Fill up fuel

Irrelevant features may be

- **specified by domain knowledge** "colour never causes failures"
- **deduced from cases** "in all cases colour never mattered"

A feature F is irrelevant for a solution S if the case database contains problem descriptions P_i => S where (i) the P_i differ only by values of F and (ii) all possible values of F occur.

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Generalization of Cases (2)

2. Inductive generalization

Problem	
Failure:	engine pinging
Car Type:	VW Polo
Fuel type:	Normal
Speed:	140
Solution	
Fuel type:	Super

Problem	
Failure:	engine pinging
Car Type:	VW Polo
Fuel type:	Normal
Speed:	150
Solution	
Fuel type:	Super

Problem	
Failure:	engine pinging
Car Type:	VW Polo
Fuel type:	Normal
Speed:	140 .. 150
Solution	
Fuel type:	Super

Heuristic:
If two cases differ only by a range-valued feature F with values V_1 and V_2, respectively, then generalize to a case with value range V_1 .. V_2.

Version-Space Learning (VSL) is a well-founded method for learning general concepts from positive and negative examples (coming soon).

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Case Adaptation

Current case:

Problem	
Car type:	Mercedes
Fuel type:	Diesel
Failure:	Engine does not start
Fuel gauge:	Empty
Solution	
?	

Retrieved case:

Problem	
Car type:	VW
Fuel type:	Gasoline
Failure:	Engine does not start
Fuel gauge:	Empty
Solution	
Action:	Fill up tank
Fuel type:	Gasoline

Adaptation heuristic:

If the problem descriptions of current case and retrieved case differ by values V and V´ for a common feature F, and F is also contained in the solution description, then adapt the solution description accordingly.

Adapted solution for current problem:

Solution	
Action:	Fill up tank
Fuel type:	Diesel

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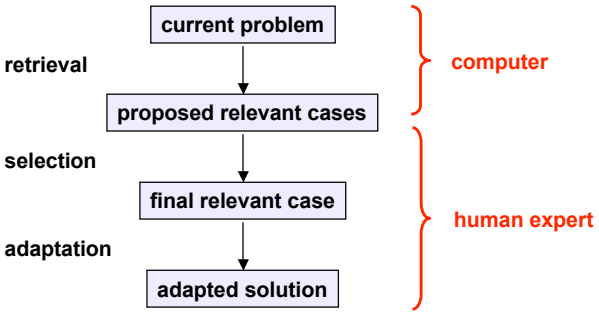
Practical Use of Case-based Problem Solving

Division of labour in many practical applications:



If humans do selection and adaptation, the main task for knowledge-based assistence systems is systematic case description and retrieval.

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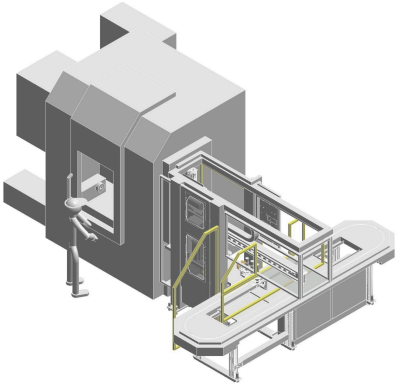
Case Study: Case-based Assistence for Fault Diagnosis in a Flexible Manufactoring System

Study for Deutsche Airbus: Conceptual design for case representation, reasoning and user interface.

Main user modes:

- **Failure handling**
  - Decribing a failure
  - Diagnosing a failure
- **Browsing**
  - Inspection of case database
  - Statistical evaluation
- **Case database administration**
  - Entering new cases and editing cases
  - Ontology extensions



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Failure Description

Failure description in 3 parts:

- **Failure situation**
  - What is the failure?
  - Under which conditions did the failure occur?

  } **problem**
- **Diagnosis steps**
  - Suspected Reasons
  - Tests
- **Therapy**

} **solution**

Use of menu-based terms
- **to ease failure description by human operators**
- **to improve retrieval**

System comprises a standard terminology.

Terminology can be modified or extended interactively by administrator

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Example of an Informal Failure Description

Failure:	**On start-up of the spindle, the fuses of the drive amplifiers are sporadically actuated.**
Guess:	**Spindle tachometer is faulty (clutch or bearing).**
Test:	**Spindle tachometer disassembled and tested. Fault remains.**
Guess:	**Faulty modules in drive amplifier.**
Test:	**Replacement of modules. Failure remains.**
Guess:	**Faulty thyristors.**
Test:	**Function of thyristors tested, no fault.**
Guess:	**Field rectifier faulty.**
Test:	**Function of field rectifiers tested, faulty.**
Therapy:	**Replacement of field rectifiers, failure removed.**

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Formal Description of a Failure Situation (1)

Completeness principle:

- **Give all information which is necessary to reconstruct the failure situation**
- **Omit information which is self-evident or does not concern the failure**

Example:

Friday 13.1.93, 16:32
Working on work piece A with program B
Work-hall temperature 19 degree
Work piece correctly mounted
Tool correctly mounted
Lubrication flow ok
On start-up of the spindle, the fuses of the drive amplifiers are actuated.

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Formal Description of a Failure Situation (2)

Formalized description of failure situation in terms of one or more observations

Each observation is described by 3 kinds of information:

Where?	**Specification of location in terms of a component**
What?	**Kind of faulty behaviour**
When?	**Specification of context**

Example:

Where?	**fuse of drive amplifier**
What?	**activated**
When?	**on start-up of the spindle**

The operator must be given the tools to specify the where, what and when of a failure.

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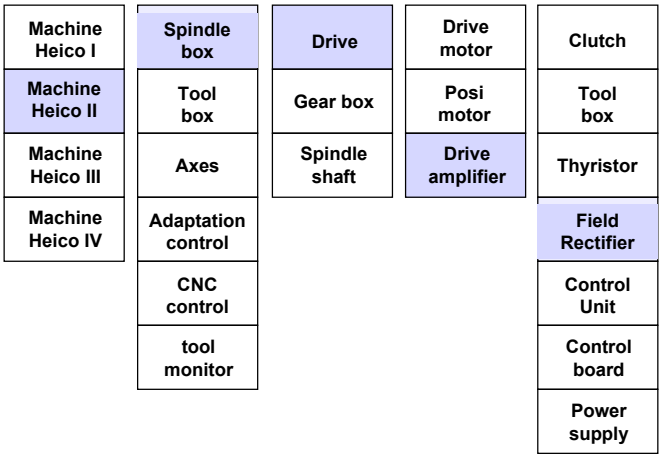
Specification of Components (1)

1. Selection via tree structure of components offered in user interface



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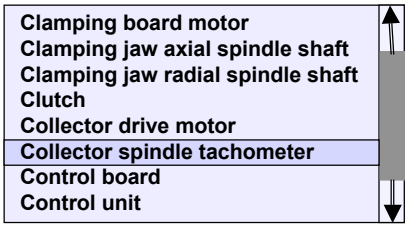
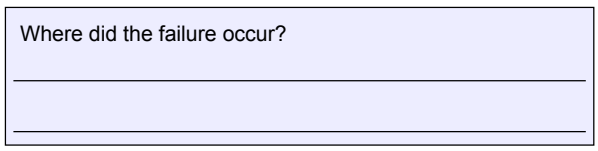
Specification of Components (2)

2. Selection via alphabetical list



3. Selection via text field
(only if selection method 1. and 2. do not offer the proper selection)



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Temporal Information

Specification of the relative temporal position of the failure incident w.r.t. known phases or time points of the operating cycle of the manufacturing system

Examples:

"before tool change"

"during work piece feeding"

"sporadically on drive-up of the spindle"

Each temporal specification consists of one or more temporal constraints. A temporal constraint usually consists of

- **a temporal reference** e.g. tool change
- **a temporal relation** e.g. before, after, during

Selection of temporal references and relations is supported by tree structures, by an alphabetical list or a text field.

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Diagnosis Steps

A diagnosis step consists of

- **a guess** about correct or faulty component behaviour
- **a test** which confirms or falsifies a guess or leaves it open

Guesses are specified similar to observations by

- **where?** a component specification
- **what?** a behaviour specification
- **when?** an optional temporal specification

A diagnosis step is concluded by confirmation or falsification.

A diagnosis step is aborted by a new guess.

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Tests and Therapies

Tests are freely phrased instructions including results.

Similarly, therapies are freely phrased instructions.

Unified phrases are not required as cases are only retrieved by observations.

Example of test description:

Disassembly of spindle tachometer

How?

Open drive case
Open tachometer case at front side
Remove tachometer generator
Inspect brushes and collector
Test continuity of ancor circuit

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Linguistic Support

The vocabulary for observations is structured by semantic relations:

- **IS** **synonym of**
- **IS-A** **specialization of**
- **PART-OF** **constituent component of**

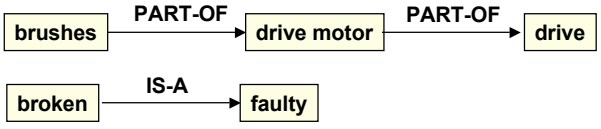
Semantic relations are exploited for the selection of relevant cases.

Example:

Current case: drive is faulty

Stored case: brushes of drive motor are broken

Stored case can be related to current case using PART-OF and IS-A relations.



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Diagnosis Support

- Central component of the case-based support system
- Support in two ways:
  - Automatic proposal of a diagnosis step (guess + test) on entering a specific failure situation
  - Automatic proposal of a diagnosis step on entering a specific guess

A relevant diagnosis step is determined by retrieving a case with similar failure situation or similar guess.

If several cases are similar, the case with the cheapest diagnosis step is offered.

If no case is similar, the user has to determine diagnosis steps himself and enters the diagnosis steps as a a new case description.

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Browsing in the Case Database

Browsing is an operating mode useful for many purposes:

- Main operating mode for database administrator
- Retrieval of diagnosis steps by active search
- Evaluation of machine performance

Example for retrieval pattern:

Date:	1991
Operator:	
Failure case:	where? drive amplifier
	what? faulty
	when?

Retrieval of all cases involving failures of the drive amplifier in 1991.

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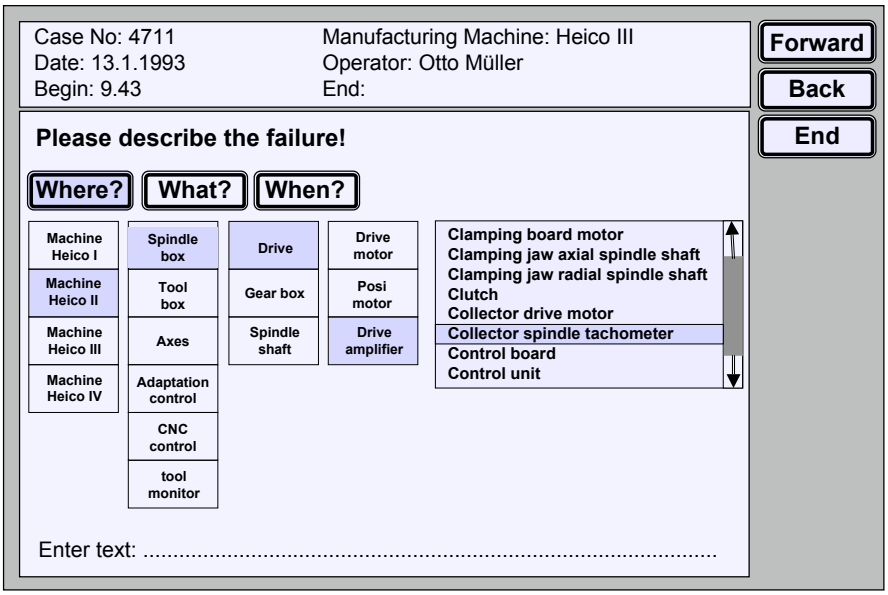
Screen Design for Failure Description



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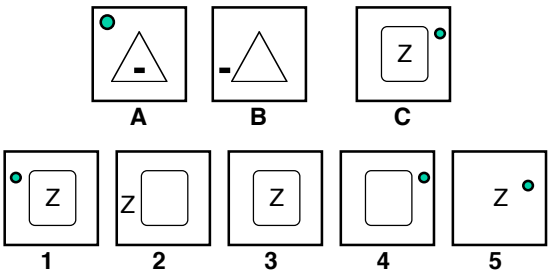
Intelligence Tests as Case-based Problem Solving



A is related to B as C to {1, 2, 3, 4, 5}?

Computational solution by Evans (1968):

- **Structural description of geometrical figures**
- **Adaptation of transformation A-C by abstraction**

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