Lecture
Case-Based Reasoning
(Fallbasiertes Schließen)
WS 2015/16
§0 Basic Introduction

Dr. Armin Stahl
Insiders Technologies GmbH
Product Management

E-Mail: a.stahl@insiders-technologies.de
Personal Introduction
History & Current Employer
1993-2000: Computer Science at University of Kaiserslautern


2004: Ph.D. at the University of Kaiserslautern
  • Title of Ph.D. Thesis: „Learning of Knowledge-Intensive Similarity Measures in Case-Based Reasoning“

2004-2012: Senior Researcher at DFKI and Lecturer at University of Kaiserslautern
  • Lecture “Case-Based Reasoning“
  • 2005-09: Deputy Head of “Image Understanding and Pattern Recognition” Department at DFKI
  • 2010-12: Head of Competence Center “Multimedia Analysis and Data Mining”

Since 2013: Product Manager at Insiders Technologies GmbH
Intelligent Software for Document Processing

From Spin-off to a Global Player

Dr. Armin Stahl | Insiders Technologies GmbH
Insiders Technologies

Insiders is one of the leading vendors of intelligent solutions for business process optimization and document understanding.

Business: Intelligent document processing and business process automation

Market entry: 1998

Customers: > 1000

Target markets: Insurance, Financial Services, Retail, Manufacturing

Sites: Kaiserslautern, Berlin, Munich

History: Spin-off of the DFKI
Multi-channel document input
Traditional processing of business mail
Core product smart FIX

1. Interfaces to all input channels
2. Classification and extraction of relevant data
3. Verification of extracted data
4. Intelligent connection to business processes

- PDF/A
- ARCHIV
- CRM / ERP

A B C D
Insiders produkt portfolio
Worldwide installations
Research Network

Insiders Technologies is a spin-off of the DFKI and closely linked with research institutes and universities.
Lecture
Case-Based Reasoning
Organizational Issues
Organisational Issues

- Lecture: every Friday 13:45 – 15:15 am in room 46/260
  - last lecture 2015: 18.12.2015
  - first lecture 2016: 08.01.2016

- Slides in the web:
  http://agd.cs.uni-kl.de/teaching/ws1516/cbr/

- Consultation hours:
  by appointment (email)

- Exam
  - Date: tba. (probably in February)
Exercises:

- Tutor: Tewodros Habtegebrial
  - Contact: tedyhabtegebrial@gmail.com
- Date: Thursdays, 10:00-10:50 (starting November 26th!)
- Room: 46-268
Structure of the Lecture

- § 1 Motivation and Introduction
- § 2 Case Representation
- § 3 Similarity Measures
- § 4 Retrieval Algorithms
- § 5 Adaptation Approaches
- § 6 Learning Approaches
- § 7 CBR in Industrial Practice

- References to literature for specific topics will be given separately in the corresponding lectures.
Lecture
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§1 Motivation & Introduction

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§ 2 Case Representation

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§ 4 Retrieval Algorithms

§ 5 Adaptation Approaches

§ 6 Learning Approaches

§ 7 CBR in Industrial Practice
§1 Motivation & Introduction

- Motivation
- Categorization
- Basic Idea of Case-Based Reasoning
- Simple Example
- CBR Process Model
Goal of Artificial Intelligence
• Development of „smart” computer systems

What makes a computer system smart?
• ...
• ...
• ...
• ...
• ...
• ...
• ...

Any Ideas?
Goal of Artificial Intelligence

- Development of „smart” computer systems

What makes a computer system smart?

- If it is able to interact with its environment autonomously?
- If it is able to make decisions autonomously?
- If it is able to learn?
- If it is able to solve more or less complex problems?
- If it is able to draw conclusions from given knowledge?
- If it is able to support a user during problem solving?
- …
Where are AI systems used today?

- Robocup
- Navigation system
- Computer gaming
- Speech recognition
- Technical diagnosis
- Optical character recognition
Branches of Artificial Intelligence

Technology-Oriented
- Logical Reasoning
- Probabilistic Reasoning
- Constraint Satisfaction, Search, and Optimization
- Pattern Recognition
- Machine Learning
- Rule-based Systems
- Agent-based Systems
- Knowledge Representation
- Knowledge-based Systems
- …

Application-Oriented
- Information Retrieval
- Planning and Scheduling
- Game playing
- Data Mining
- Computer Vision
- Natural Language Processing
- Robotics
- …
Many relations and overlaps between AI branches

However, many research communities have their own view on the world

- these views are often based on different assumptions & paradigms
- these views may even contradict

What does that mean for you? 😊

- You may hear different opinions in different lectures…
- You may learn different ways to solve the same problems…
  - BUT: Usually non of them is in general better or worse than others…
  - Each view / method has typically its own advantages and drawbacks…

- Finally, you should develop your own view on the world! 😊
Branches of Artificial Intelligence

- **Technology-Oriented**
  - Logical Reasoning
  - Probabilistic Reasoning
  - Constraint Satisfaction, Search, and Optimization
  - Pattern Recognition
  - Machine Learning
  - Rule-based Systems
  - Agent-based Systems
  - Knowledge Representation
  - Knowledge-based Systems
  - …

- **Application-Oriented**
  - Information Retrieval
  - Classification and Diagnosis
  - Planning and Scheduling
  - Game playing
  - Data Mining
  - Computer Vision
  - Natural Language Processing
  - Robotics
  - …
Application Tasks

- Classification Systems
  - E.g. credit check, Optical Character Recognition (OCR), …

- Diagnosis Systems
  - Technical Diagnosis
  - Medical Diagnosis

- Configuration Systems
  - Configuration of technical systems, applications in architecture

- Planning Systems
  - Route planning, action planning, etc.
Knowledge-Based Systems

- Highly specialized “smart” systems
- Are based on a knowledge base
- Often also called expert systems
- Typically focus on a specific application domain
- Often used as assistant systems
Architecture of Knowledge-Based Systems

Problem / Query

Example: Planning
Start and Goal
Example: Diagnosis
Symptoms

Example: Planning
Route description
Example: Diagnosis
Diagnosis & Therapy

Solution

Knowledge Base

User Interface

Inference Mechanism

Knowledge-based System

Example:
Planning
Route description
Example:
Diagnosis
Diagnosis & Therapy

Example:
Planning
Start and Goal
Example:
Diagnosis
Symptoms
Knowledge-based Systems can be implemented by applying different methodologies

- use of different kinds of knowledge and knowledge representations
- use of different inference mechanisms

3 Major Approaches:

- Rule-based
- Model-based
- Case-based
Kinds of Knowledge

- **General Knowledge**
  - Statements and principles of general validity
  - May go over a specific universe of discourse
  - Can be applied in many different situations
  - Examples: Rules, laws, principles
    - E.g. $U = RI$ (Ohm’s law)

- **Specific Knowledge**
  - Limited universe of discourse
  - Very limited validity
  - Examples: Facts, specific observations
    - E.g. “Through a resistor of 10 Ohm flows a current of 500mA given a voltage of 5 Volt.”
Experience is …

- specific knowledge,
- obtained from a specific problem solving context,
- typically stored in a memory.

Advantages and Drawbacks

- + easier to obtain than general knowledge
- + often more up to date than general knowledge
- + sometimes easier to reuse through the given context
- - reusability is limited
- - has typically a large data volume
Rule-Based Approach

- Idea: Representation of knowledge by using \textbf{rules} and \textbf{facts}
- Rules are of the form “IF <precondition> THEN <conclusion>”
- Typically rules have to be defined by domain experts
- Drawing of conclusions by evaluating rules and facts
- Typical example: PROLOG

Properties

- + a complete and correct rules base guarantees correct conclusions
- - high knowledge acquisition and maintenance effort
- - handling of uncertainty and incomplete knowledge is problematic
Model-Based Approach

- Idea: Representation of knowledge by a general domain model
- Model generation
  - Defined by domain expert
  - Automatically learnt from specific knowledge (training data)
- Examples of Models:
  - Explicit statistical models, e.g. given by probability distributions
  - Decision Trees, Bayesian Networks, Neural Networks, etc.

Properties

- + a “good” model allows reliable conclusions
- - the generation of a good model is not trivial and time consuming
- - a model is often a simplified view on the world
- - results of model-based approaches are often difficult to interpret
Case-Based Approach

- Idea: Drawing conclusions directly from stored situation-specific experience knowledge
- Experience knowledge as a tuple of a problem and corresponding solution description – called case
- Solving of new problems by transferring solutions of similar, already solved problems
- Basic assumption: “Similar problems have similar solutions”
The Basic Idea of Case-Based Reasoning

- Basic Idea
  1. Retrieving relevant experiences from the case base
  2. Reusing of retrieved experiences in the context of the current problem (may require adaptation of the retrieved solution)
  3. Storing of the new experience in the case base (learning)
Properties

- + cases are often directly available
- + inference mechanism is easy to understand and explainable
- + exceptions can be handled easily
- - correctness of generated solutions cannot be guaranteed
- - problem solving may be time consuming when dealing with large case bases
# Knowledge-Based Systems: Approaches Comparison

<table>
<thead>
<tr>
<th></th>
<th>Rule-based</th>
<th>Model-based</th>
<th>Case-based</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge Base</strong></td>
<td>Rules, Facts</td>
<td>Model</td>
<td>Cases &amp; Background Knowledge</td>
</tr>
<tr>
<td><strong>Inference Mechanism</strong></td>
<td>rule chaining</td>
<td>depends on the used model</td>
<td>similarity</td>
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<tr>
<td></td>
<td>▪ backward (Prolog)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>▪ forward (OPS 5)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Advantages</strong></td>
<td>▪ easy to understand</td>
<td>▪ high quality of conclusions</td>
<td>▪ flexibly applicable</td>
</tr>
<tr>
<td></td>
<td>▪ correctness can be guaranteed</td>
<td>▪ often statistically sound</td>
<td>▪ low KA effort</td>
</tr>
<tr>
<td></td>
<td>▪ well formalized</td>
<td>▪ learnable</td>
<td>▪ transparent, explainable</td>
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<td>▪ handling of exceptions</td>
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<td></td>
<td></td>
<td></td>
<td>▪ learnable</td>
</tr>
<tr>
<td><strong>Drawbacks</strong></td>
<td>▪ high KA effort</td>
<td>▪ often not transparent and explainable</td>
<td>▪ correctness cannot be guaranteed</td>
</tr>
<tr>
<td></td>
<td>▪ problems to deal with uncertainty</td>
<td>▪ problems to deal with exceptions</td>
<td>▪ no clear formal foundation</td>
</tr>
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§1 Motivation & Introduction
Case-Based Reasoning is ...

1. … an **engineering approach** for developing and implementing intelligent systems.
   - Technical and computer science point of view
   - Goal: Development of practical systems

2. … a **cognitive approach** for modeling human problem solving behavior.
   - Cognitive science point of view
   - Goal: Understanding of cognitive procedures
Statements about Case-Based Reasoning

- “Case-based reasoning is [...] reasoning by 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 and 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)
Use of Cases by Humans

- ... 
- ... 
- ... 
- ... 
- ... 
- and many more
- ...and many more

Any Ideas?
Use of Cases by Humans

- A **doctor** remembers the history of **disease** of another patient.
- A **technician** remembers a similar **failure** of a technical system.
- A **lawyer** argues with a similar **precedent**.
- An **architect** studies the **plan** of an existing building.
- A **mathematician** tries to transfer a known **proof** on a new problem.
- A **researcher** uses a research **proposal** of the past as template for writing a new proposal.
- ...and many more