

Of Analogies and Episodes



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ATA 2023 Workshop:
Analogies: from Theory to Applications
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Overview

- Goals of the talk
- A classic perspective from early cognitive science
- Differences and similarities of analogy and CBR
- Opportunities for leveraging CBR with analogy
- Conclusions



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Goals of the Talk

- To place analogy and CBR in context of each other
- To present a personal view of their relationship
- To discuss why (and how) analogy and CBR need each other
- To propose paths for integrating analogy and CBR

Note: The material will be highly selective, focusing on key perspective rather than recent directions.



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Complimenting Jean Lieber's Afternoon Talk



Jean Lieber

Associate Professor in
computer Science
University of Lorraine
(France)

Case-Based Reasoning and Analogy: a Turbulent Love Story

Jean will examine latest work / analogical
proportions



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Ongoing Discussion Welcome!



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What is an Analogy?



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A Classic Perspective, by Dedre Gentner

- *Analogies are partial similarities between different situations that support further inferences. Specifically, analogy is a kind of similarity in which the same system of relations holds across different objects.*

Quoted from Gentner, 1998



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Gentner's View of Analogical Mapping

- *The core process in analogy is mapping: the process by which one case is used to explain and predict another.*
- *In mapping, a familiar situation - the base or source analog provides a kind of model for making inferences about an unfamiliar situation - the target analog.*
- ...

Quoted from Gentner, 1998



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- According to [structure-mapping theory], an analogy conveys that a system of relations that holds in the base domain also holds in the target domain, whether or not the actual objects in the two domains are similar.
- The alignment must be structurally consistent:
 - there is one-to-one correspondence between elements in the base and elements in the target, and
 - the arguments of corresponding predicates must also correspond (parallel connectivity).
- A further assumption is the systematicity principle: systems of relations connected by higher-order constraining relations such as cause contribute more to analogy than do isolated matches or an equal number of independent matches...

Quoted from Gentner, 1998

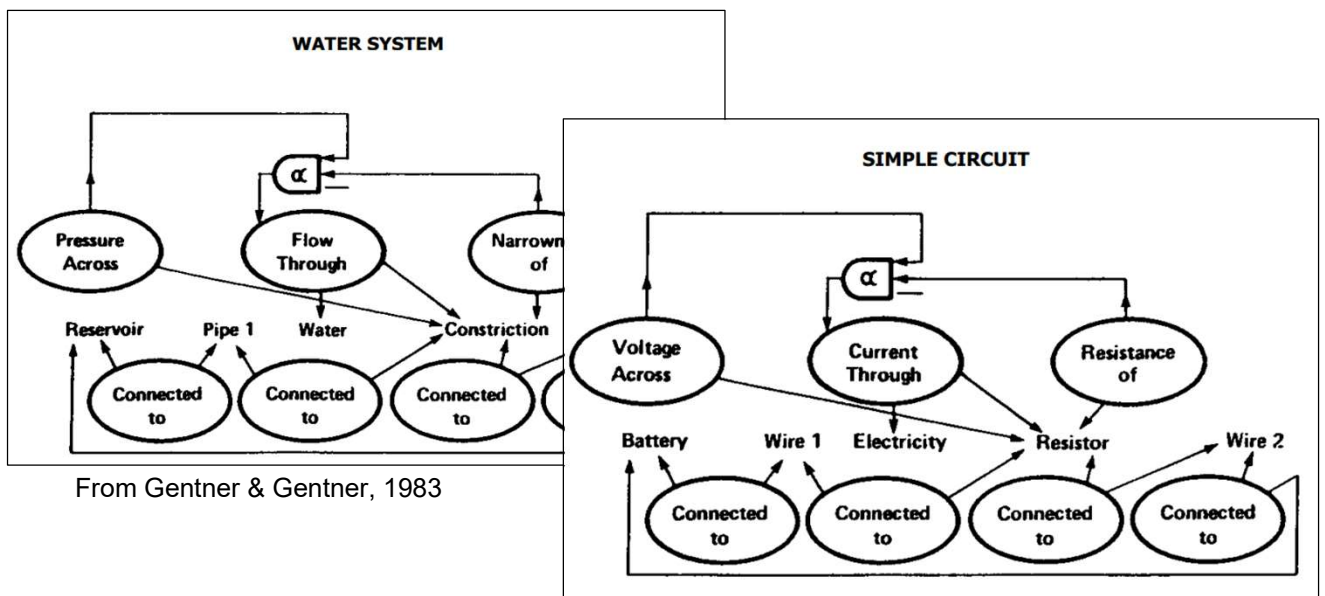


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Water System and Simple Circuit



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Could Analogy be CBR? Is CBR Analogy?

- Looking closely:
 - *The core process in analogy is mapping: the process by which one case is used to explain and predict another.*
 - *In mapping, a familiar situation - the base or source analog provides a kind of model for making inferences about an unfamiliar situation - the target analog.*

Sounds familiar for CBR 😊



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Could Analogy be CBR? Is CBR Analogy?

- Looking closely:
 - *The core process in analogy is mapping: the process by which one case is used to explain and predict another.*
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Sounds familiar for CBR 😊

Is something missing for CBR?

What about case adaptation?



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Can We Find Adaptation Here?

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For CBR, maybe, maybe not, depending on task...



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Different Approaches to Analogical Mapping Suggest Different Stances for Case Adaptation

- Gentner's (1998) characterization of mappings:
 - Projection-first: Abstract the base and verify/align with the target (Keane's IAM, Hummel & Holyoak's LISA)
 - Alignment-first: Falkenhainer, Forbus & Gentner's SME, Holyoak & Thagard's ACME)



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Perhaps the Difference is Goals?

- Analogy focuses on mapping—which may be used to solve a problem
- CBR maps cases *to solve problems*
- Thus what matters to CBR is strongly context-dependent



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Compare to Perspectives on Pragmatic Factors in Analogy

- Illustrations from Gentner (1998)
 - Holyoak “defined analogy as similarity with respect to a goal and suggested that mapping processes are oriented towards attainment of goal states”
 - “Holyoak and Paul Thagard (1989) combined this pragmatic focus with the assumption of structural consistency and developed [an] approach to analogy in which similarity, structural parallelism, and pragmatic factors interact to produce an interpretation.”



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Pragmatic and Adaptation Factors in Human Cognition

- Keane (1994) showed evidence suggesting that pragmatic factors *may not* play a role in selecting mappings, but...
- Adaptation does: “a mapping will be selected if it is evaluated as being easily adapted relative to other competing mappings”



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The Relationship: My First View

(Leake, 1996)

- CBR = Memory + Analogy + Adaptation + Storage
- In this model,
 - Analogy determines relevant relationships between an old case and a new episode
 - However, their importance is discretionary: *A bad analogue may be a useful case*



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Differences Between Analogues and Cases 1

- The importance of deep match
 - For a good analogue, the deep match is what matters
 - In a case, *the solution* is what matters
 - The solution may or may not have deep structural match: CBR can reason from raw episodes without internal structure, or whose internal structure is unanalyzed
 - A case may be useful to problem-solving if it provides a good starting point, even if little of its deep structure matches



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Case Usefulness with Varying Match: An Example from Case-Based Explanation in SWALE

(Schank & Leake 1989; Leake 92; Schank, Riesbeck, Kass, 1994)

- System task: Case-based explanation of anomalous events
- The system's namesake example is explaining the story of the racehorse Swale:

Swale was a star 3-year-old racehorse winning all the most important races.

A few days after a major victory, he returned from a light morning gallop and collapsed, dead, at his stable.



Photo by Noah Salzman, CC-BY-SA 4.0,
https://en.wikipedia.org/wiki/Horse_racing#/media/File:GGF_Race5.jpg

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Why Explaining Swale is Hard Reasoning from Scratch

- Novelty of the event
- Limited information about circumstances
- Computational cost of chaining through possible causes
- Imperfect and incomplete knowledge



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However, People Can Do It

Why did Swale die?



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Swale's Death Prompted Reminders

- A vet: “This sounds like an aneurysm. I’ve seen this sort of thing before.”
- A Yale AI lab student: “This sounds like the death of Jim Fixx “ (a runner, who died of a heart-attack when in peak condition.)
- Another lab student: “Swale was a young superstar like Janis Joplin. Maybe he died of a drug overdose.”

To what extent are these past cases analogous?
Each needs (different levels of) adaptation



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Levels of Adaptation (and of correspondence)

- Directly applicable explanation: An aneurysm
 - Result: Swale died of an aneurysm
- More distinct explanation: Heart attack from jogging
 - Problem: Horses aren't joggers
 - Adaptation: Search memory for something racehorses do with the same effects
 - More abstract match = analogy
 - Need the specifics to verify
 - Result: Find that racehorses have exertion during racing and training runs
 - Result: Swale died of a heart attack during a training run
- Routine differences require straightforward repair; adaptation generates a “similar” solution



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Joplin Explanation

- Janis Joplin explanation:
 - Stress \Rightarrow recreational drug use \Rightarrow overdose
- Problems: Racehorses can't take recreational drugs.
- Adaptation: Remove recreational drugs, keep drug overdose, and try to justify. Result:
 - *Swale died when his trainer gave an overdose of performance-enhancing drugs.*
- Lesson: When differences are major, adaptation can result in radically different solutions
- Little remains of the attempted analogy



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Revisiting the Relationship

- CBR = Memory + Analogy + Adaptation + Storage
- In this model,
 - Analogy determines relevant relationships
 - Unlike (some) analogy, lack of match need not interfere with reuse



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Opportunities

- Complimentary strengths of CBR and analogy suggest benefits for their integration
- Two illustrations:
 - Mapping as representation-building: Exploiting rich case connections to expand what to map
 - Exploiting analogies throughout the CBR process



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Mapping as representation-building: Constructive similarity assessment (Leake 1992)

- Episodes need not have firm predefined boundaries
- Mapping in CBR may define what needs to be mapped
- In the SWALE example, explanations are evaluated with dynamically-generated “cases” that can be *trimmed* or *elaborated* drawing on knowledge in memory



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Using Analogy During CBR: Retrieval Indices and Processes

Cases and potential analogies may be retrieved based on structure, e.g., Schank's TOPs, Falkenhainer, Gentner, & Forbus's MAC/FAC or Kendall-Morwick & Leake's Phala

More commonly, efficient retrieval in CBR depends on indexing or structural summarization

Rich creative CBR retrieval may be analogical

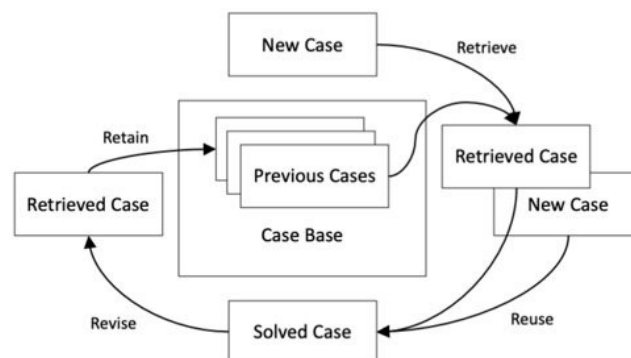


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More Broadly: Opportunities to Integrate Analogy Throughout the CBR Cycle



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Conclusions

- Boundaries between CBR and analogy are blurred
- There are many similarities, both in theory and practice
- The most important difference:
 - Analogy seeks *analogies* (not surprisingly)
 - CBR seeks *solutions*



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Opportunities for More Integrations

- Integrations can and should go beyond the top level
- The reasoning of analogy can enrich the CBR process within the CBR task in steps such as:
 - Representation building/Constructive similarity assessment
 - Indexing
 - Retrieval
 - Adaptation
 - Maintenance (retention less necessary for analogous cases)
- Already some of these have been pursued implicitly
- Next step: Making these ties and methods *explicit*



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