UNCONVENTIONAL APPROACHES TO AI

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Insights from the past

- Unconventional approaches in AI: complex systems perspectives, cognitive psychology, social sciences, computational models of creativity and other unconventional models
- This is AI or classical AI before big data. The time is now ripe to revisit these wonderful ideas and think about how to incorporate them in modern AI/deep learning. Insights from the past can inform future approaches to AI, especially in the age of big data.
- Looking at the heritage of computing and its interdisciplinary past can inspire new approaches for the future.
- We need to learn lessons from the history of AI, what approaches worked and did not work in the past and how AI went through multiple winters.
- These approaches can be used to develop techniques that can inspire explainable AI.

APPROACHES

- Narratives and stories
  - How we make sense of our complex environment
- Computational models of creativity and insight
- Case based reasoning
  - Doctors, lawyers
- Analogies
- Dreams
  - Aid generalization and prevent overfitting
- Commonsense reasoning

Computational models of creativity and insight

- We are told of eureka moments (Archimedes, newton, …)
- In reality, we always build on the work of others
- There is a preparation stage
- Incubation stage
- Retrieval/indexing (kekule dreaming of a snake and then linking it to benzene rings)

A computational model of scientific insight, Pat Langley, 1986

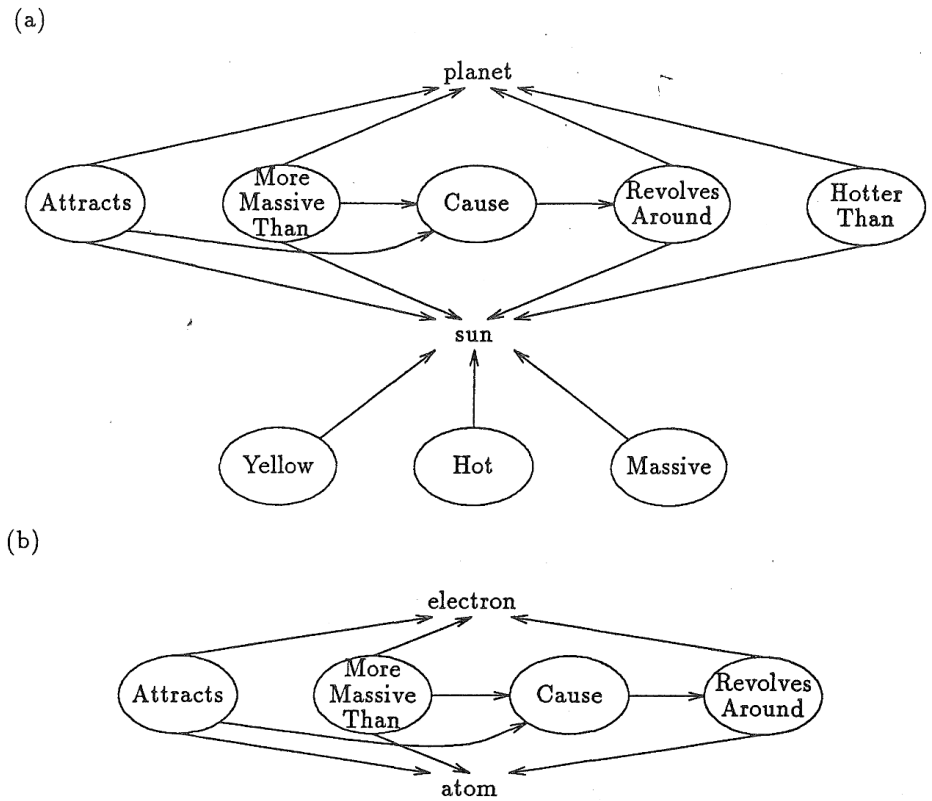


Figure 2. Creating a representation for the atom from the statement, "The atom is like the solar system." Higher order relations are carried over and simple attributes are ignored.

ANALOGIES

A COMPUTATIONAL MODEL OF SCIENTIFIC INSIGHT, 1986, LANGLEY ET AL.

ANALOGY

- Abstraction and reasoning
- Abc -> ABD
- XYZ -> ?
- ABC -> ABD
- IIJJKK -> ?

ANALOGY

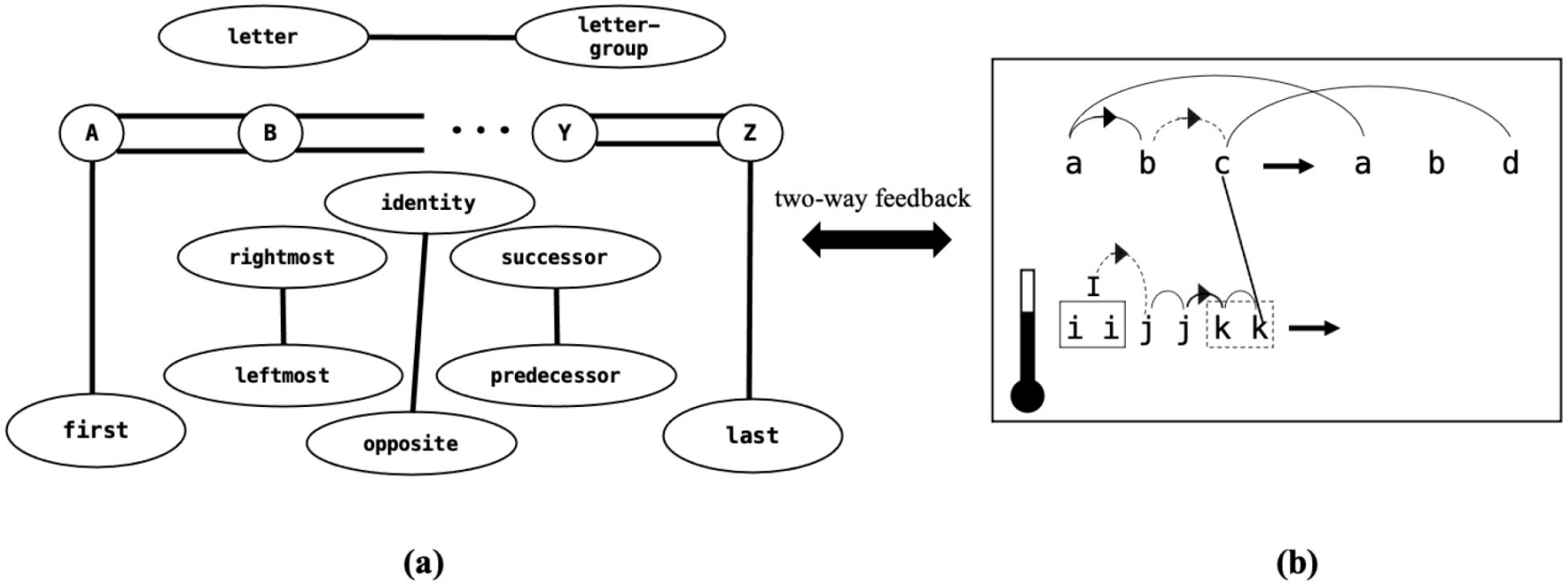


Figure 1: (a) Illustration of part of Copycat's concept network. (b) Illustration of Copycat's workspace, during a run of the program.

M. MITCHELL AND D.R. HOFSTADTER / THE EMERGENCE OF UNDERSTANDING IN A COMPUTER MODEL OF CONCEPTS AND ANALOGY-MAKING

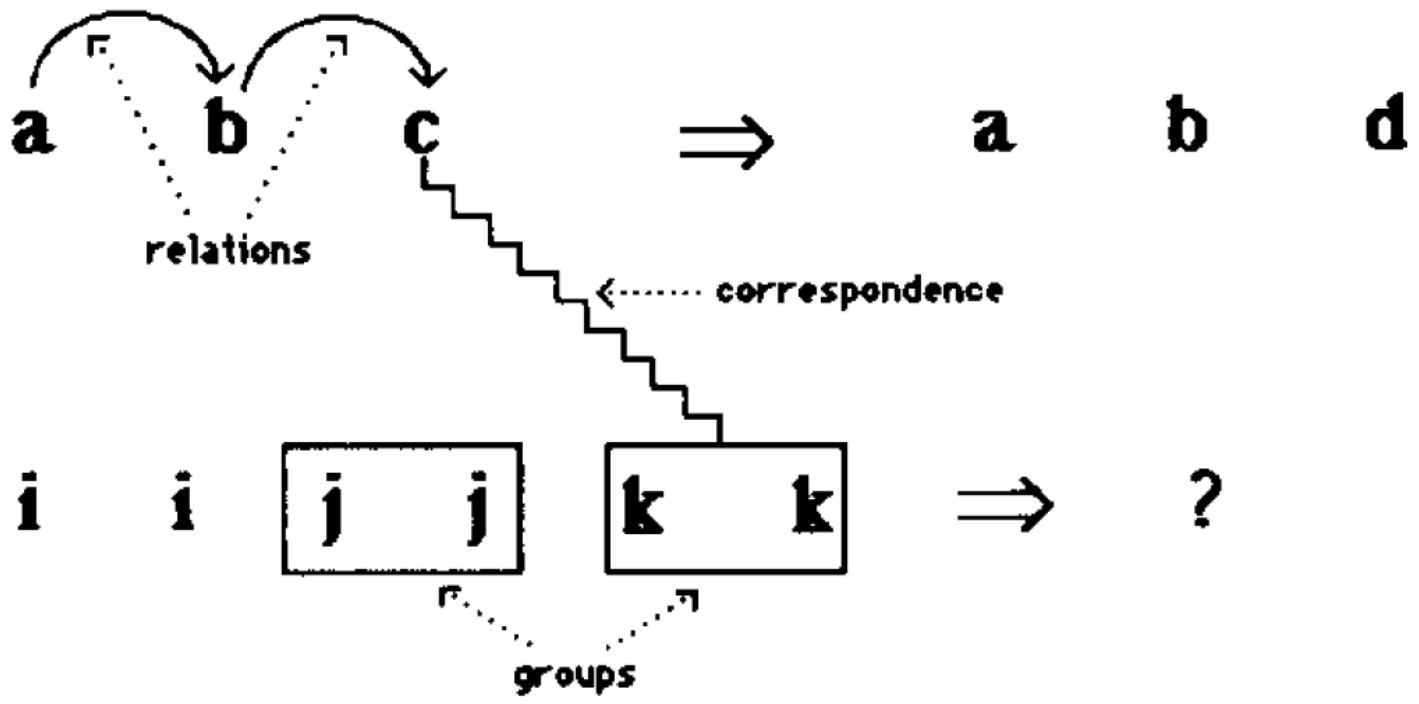
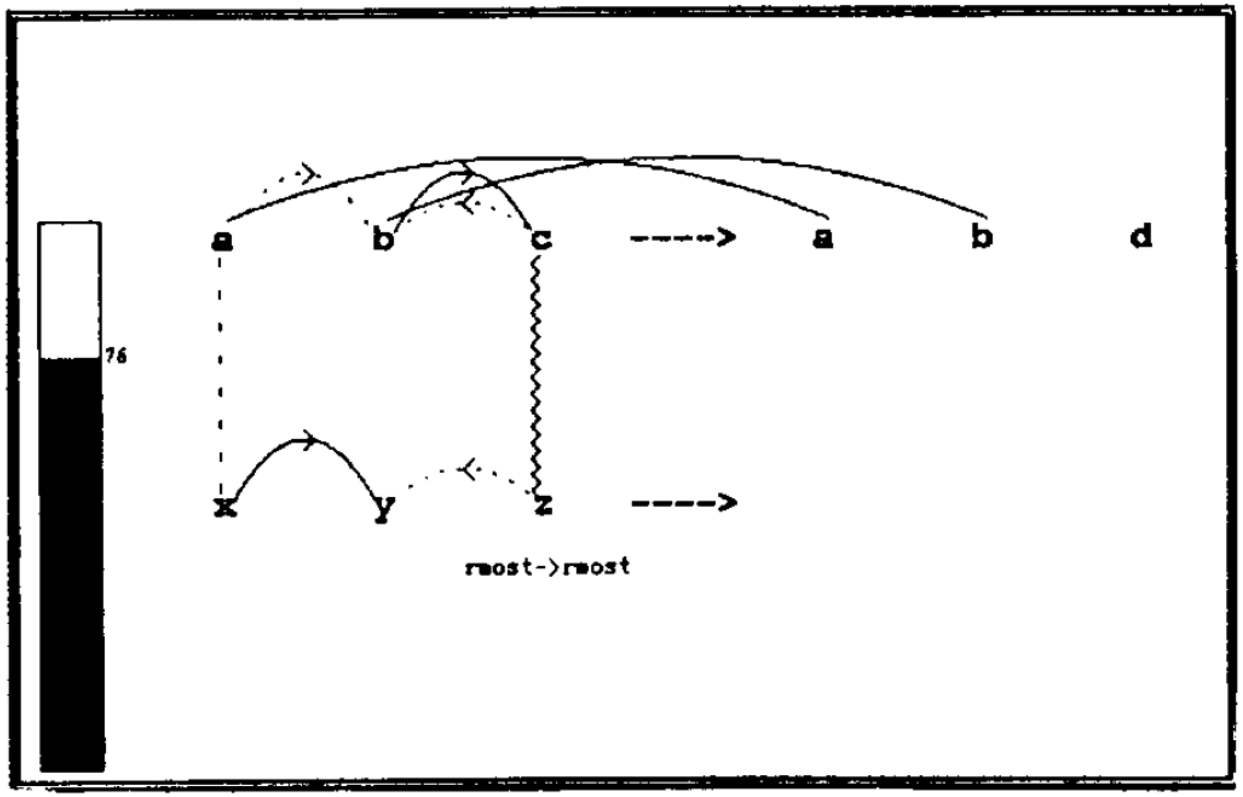


Fig. 2. Perceptual structures, including relations, groups, and a correspondence.

M. MITCHELL AND D.R. HOFSTADTER / THE EMERGENCE OF UNDERSTANDING IN A COMPUTER MODEL OF CONCEPTS AND ANALOGY-MAKING

Fig. 2 shows examples of perceptual structures that could be built in the process of solving the problem "***abc*** ⇒ ***abd***, ***iijjkk*** ⇒ ?". The types of structures built by the program include *descriptions* of objects (e.g. the ***C*** in ***abc*** is the string's *rightmost* letter), *relations* between objects (e.g. the ***B*** in ***abc*** is the *successor* of its left neighbor, the ***A***), *groups* of objects (e.g., ***jj*** is a group of adjacent identical letters; the entire string ***abc*** could be seen as a group of adjacent letters that increase alphabetically), and *correspondences* between objects (e.g. the ***C*** in ***abc*** corresponds to the group ***kk*** in ***iijjkk***). (See section 5 for examples of these structures in a run of the program.)

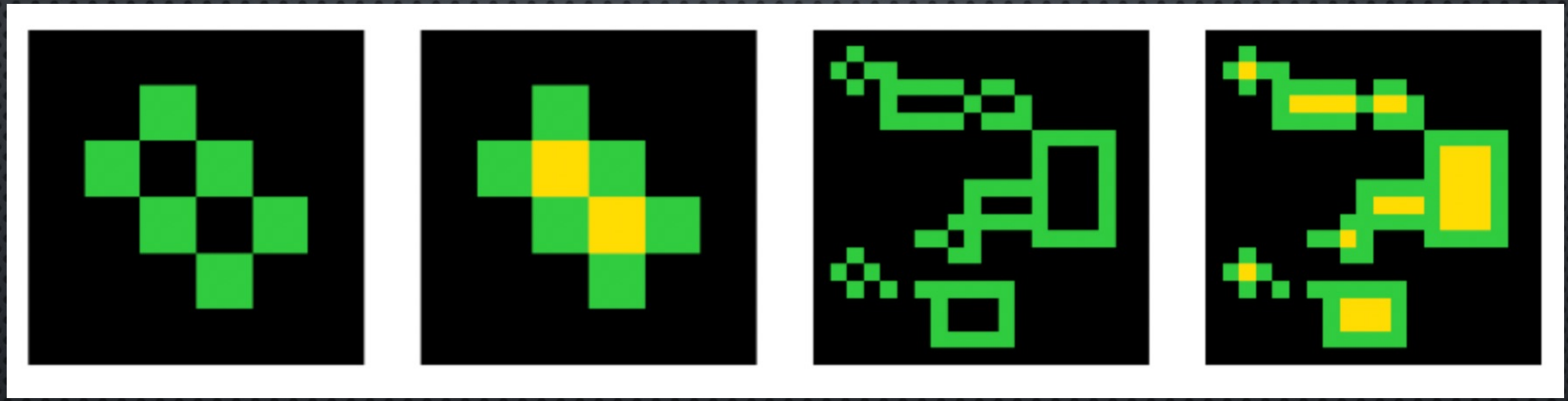
M. MITCHELL AND D.R. HOFSTADTER / THE EMERGENCE OF UNDERSTANDING IN A COMPUTER MODEL OF CONCEPTS AND ANALOGY-MAKING



3. Some relations between letters within each string have been built and others continue to be considered. Copycat, unlike people, has no left-to-right or alphabetic-forwards biases, and in general is equally likely to perceive relations in either direction, although here, *successor* tends to be activated early when the ***C***-to-***D*** change is noticed, causing the system to tend to perceive the letters as having left-to-right successor relations rather than right-to-left predecessor relations. A correspondence between the ***C*** and the ***Z*** (jagged vertical line) has been built. Both letters are *rightmost* in their respective strings: this underlying concept mapping is displayed beneath the correspondence. In response to the growing amount of structure, the temperature has dropped to 76.

M. MITCHELL AND D.R. HOFSTADTER / THE EMERGENCE OF UNDERSTANDING IN A COMPUTER MODEL OF CONCEPTS AND ANALOGY-MAKING

NEW DATA



ABSTRACTION AND REASONING CORPUS

ANALOGIES: STRUCTURE MAPPING ENGINE

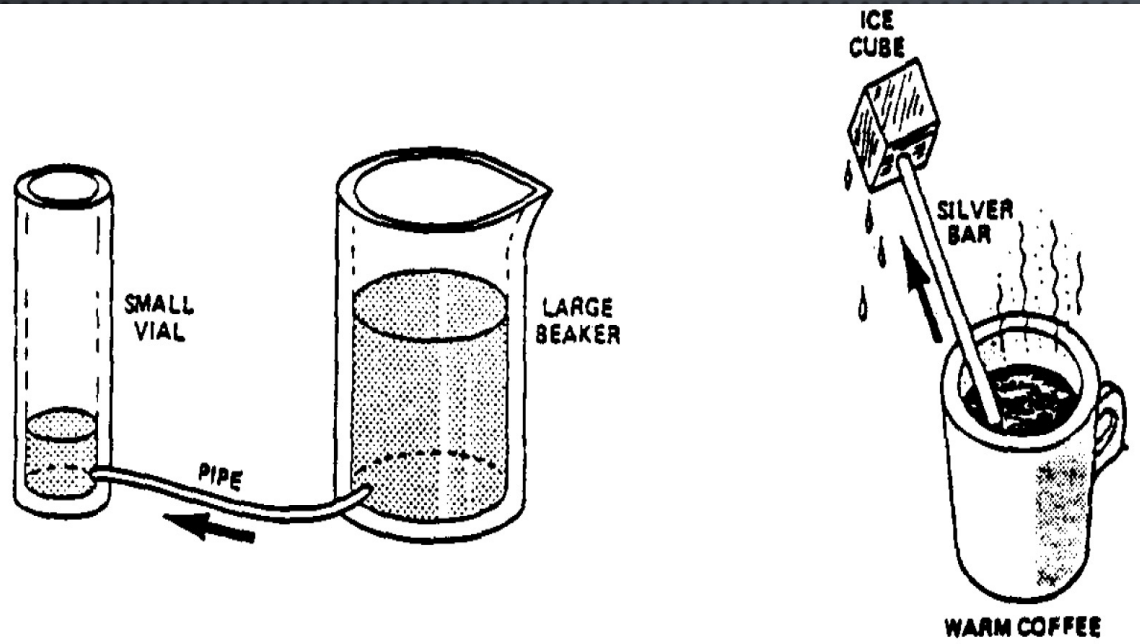


Fig. 1. Two physical situations involving flow (adapted from [3]).

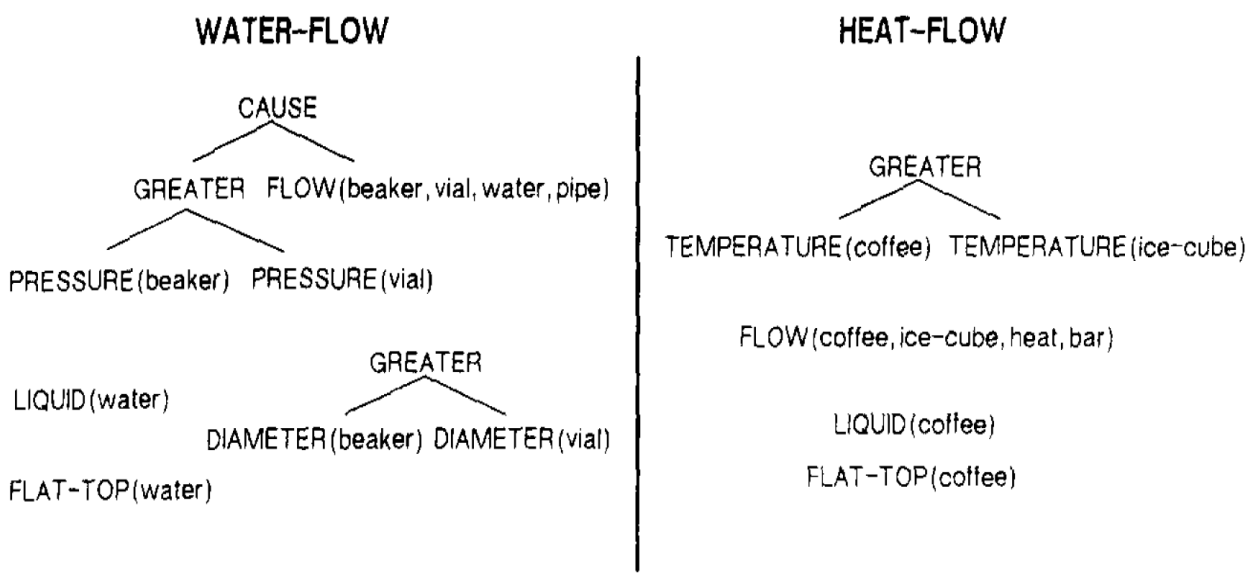


Fig. 2. Simplified water flow and heat flow descriptions.

THE STRUCTURE-MAPPING ENGINE: ALGORITHM AND EXAMPLES, FALKENHEINER & FORBUS

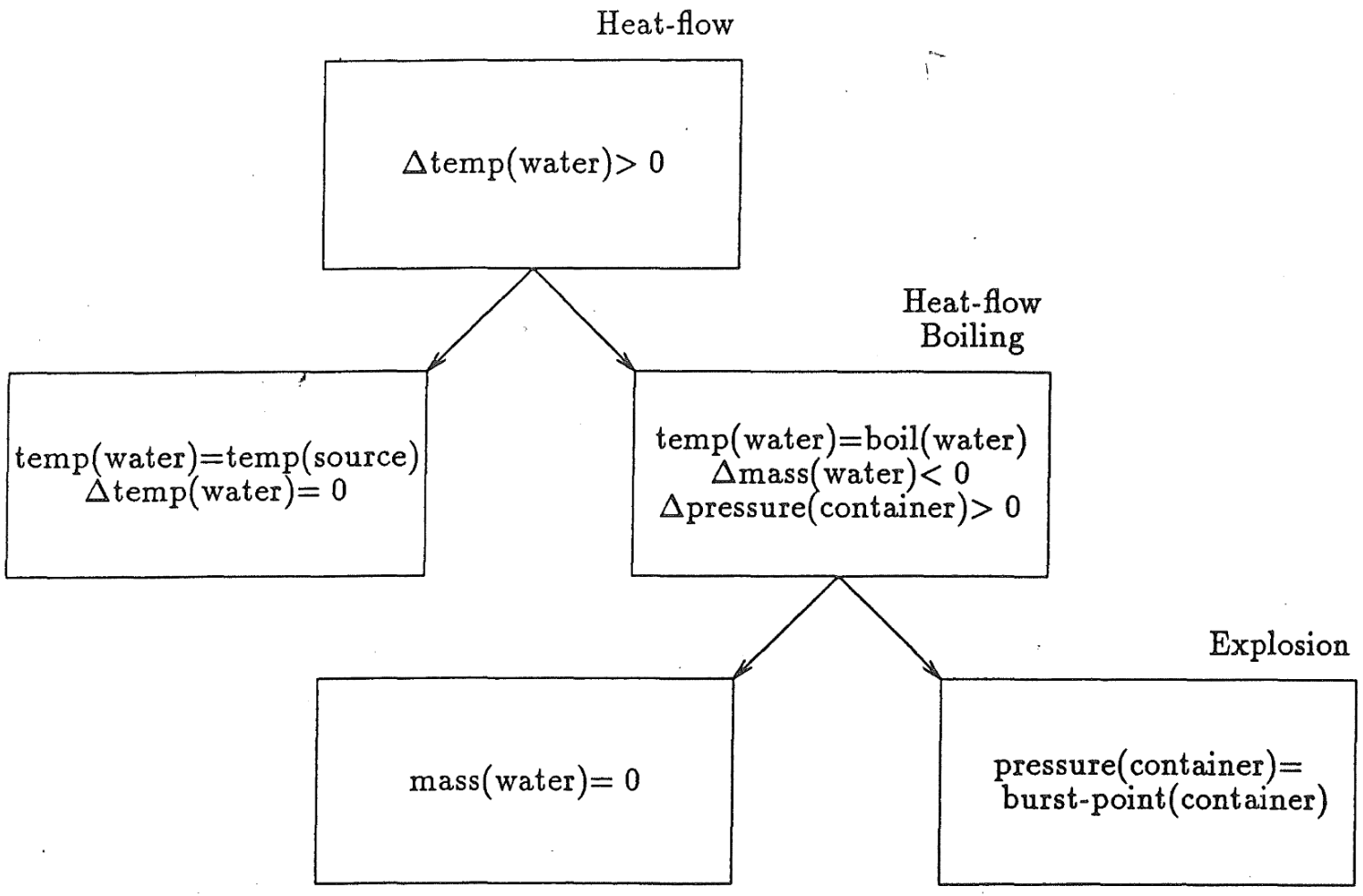


Figure 3. An envisionment for boiling water.

QUALITATIVE PROCESS MODELS

APPROACHES

- Narratives and stories (Patrick Winston)
  - How we make sense of our complex environment
- Dreams
  - Aid generalization and prevent overfitting
- Commonsense reasoning (Davis, Marcus)

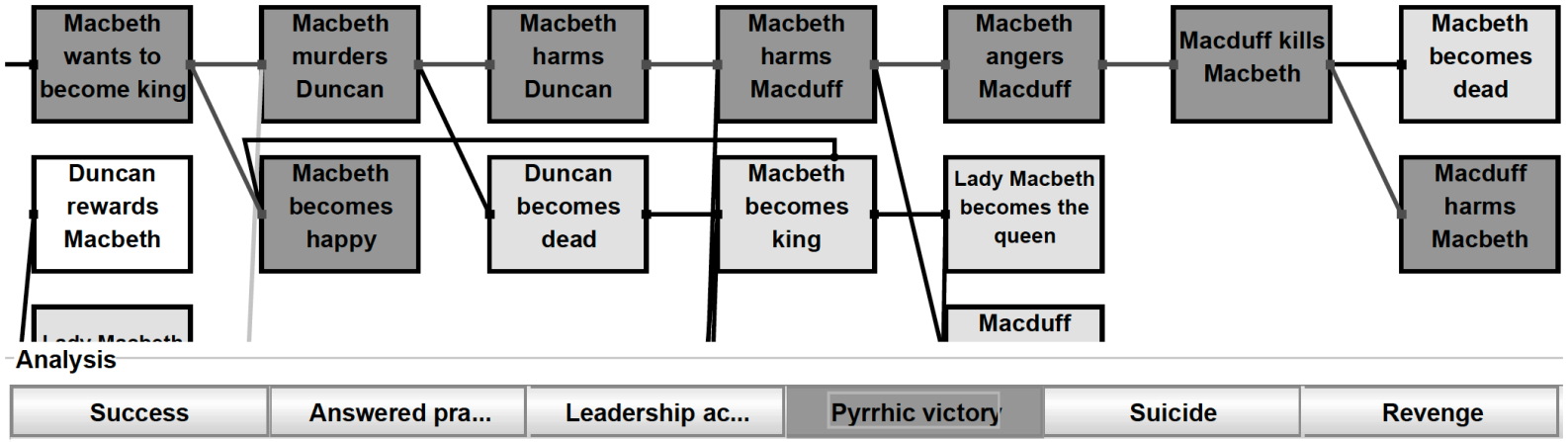


Figure 2: Genesis's story understanding system uses the elaboration graph, together with reflection patterns, to augment the explicit knowledge provided in the story and simple inferences generated using commonsense rules. Here, Genesis discovers a Pyrrhic victory, shown in dark gray.

STORY UNDERSTANDING

THE STRONG STORY HYPOTHESIS AND THE DIRECTED PERCEPTION HYPOTHESIS, WINSTON, 2011

STORIES AND ANALOGIES

1. In Search of the Bull

In the pasture of the world,
I endlessly push aside the tall
grasses in search of the Ox.
Following unnamed rivers,
lost upon the interpenetrating
paths of distant mountains,
My strength failing and my vitality
exhausted, I cannot find the Ox.

2. Discovery of the Footprints

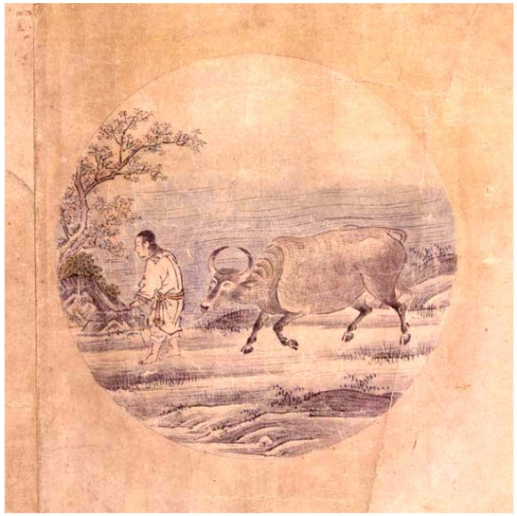
Along the riverbank under the
trees,
I discover footprints.
Even under the fragrant grass,
I see his prints.
Deep in remote mountains they
are found.
These traces can no more be
hidden
than one's nose, looking
heavenward.[web 8]

3. Perceiving the Bull

I hear the song of the nightingale.
The sun is warm, the wind is mild,
willows are green along the shore
-
Here no Ox can hide!
What artist can draw that massive
head,
those majestic horns?[web 8]

ZEN KOAN, TEN BULLS, WIKIPEDIA

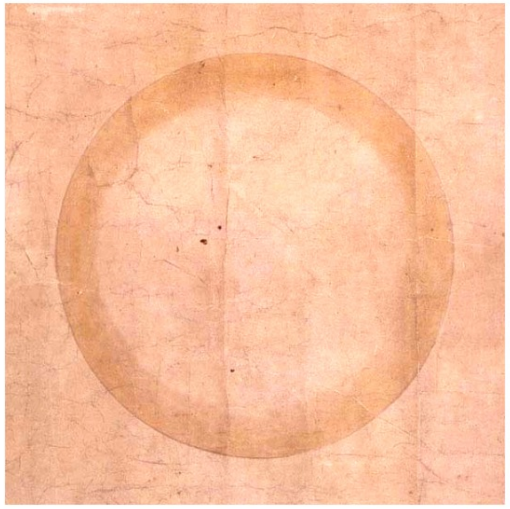
4. Catching the Bull



5. Taming the Bull

6. Riding the Bull Home

7. The Bull Transcended



8. Both Bull and Self

9. Reaching the Source

STORIES AND ANALOGIES

ZEN KOAN, TEN BULLS, WIKIPEDIA

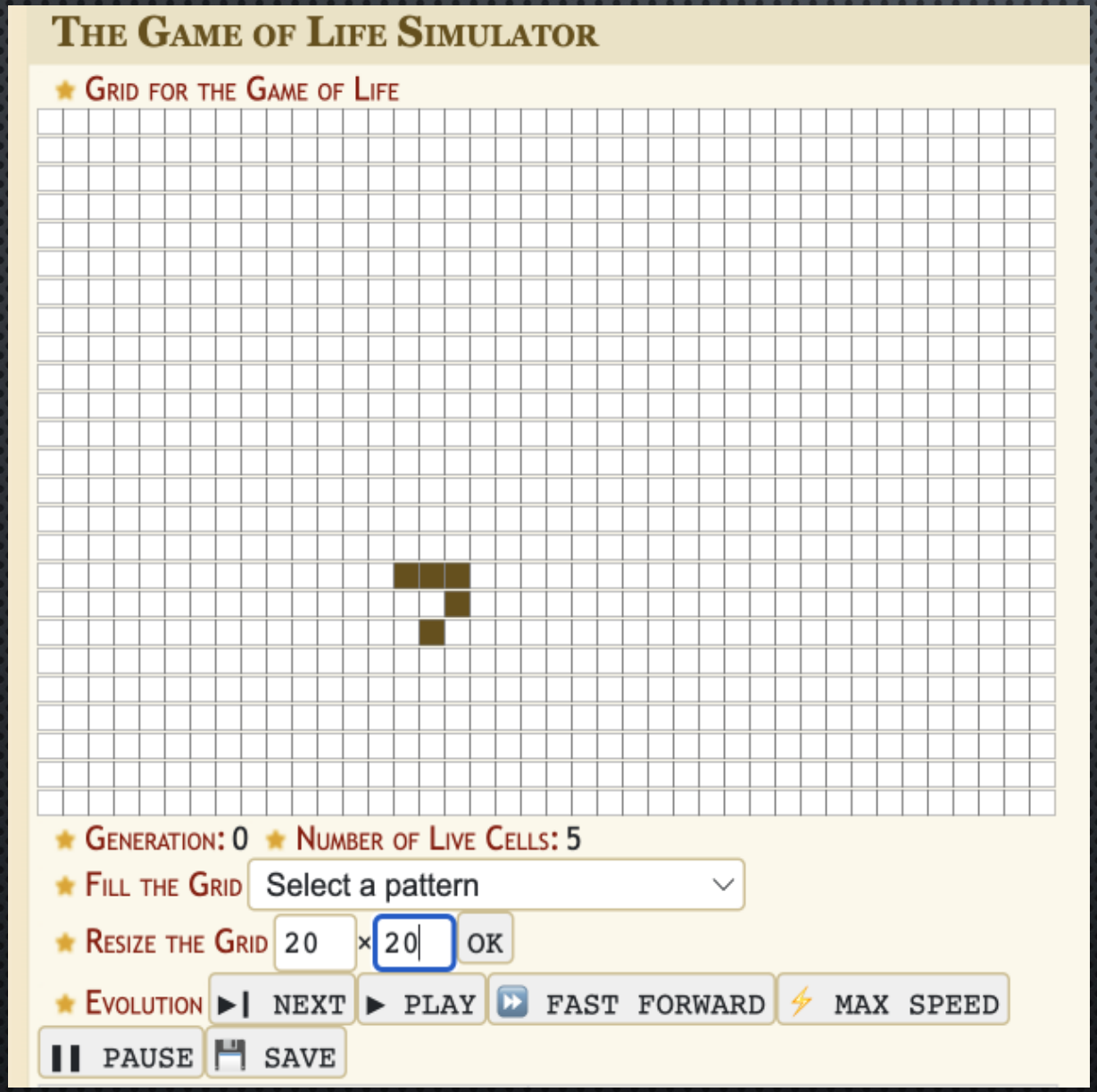
Collective Intelligence

- Other ideas
  - Other paths to intelligence (in other species)
  - Collective intelligence

COLLECTIVE INTELLIGENCE

- Task allocation and division of labour
- Complex nest architecture
- No central designer
- No individual has design for complete structure
- *Stigmergy*

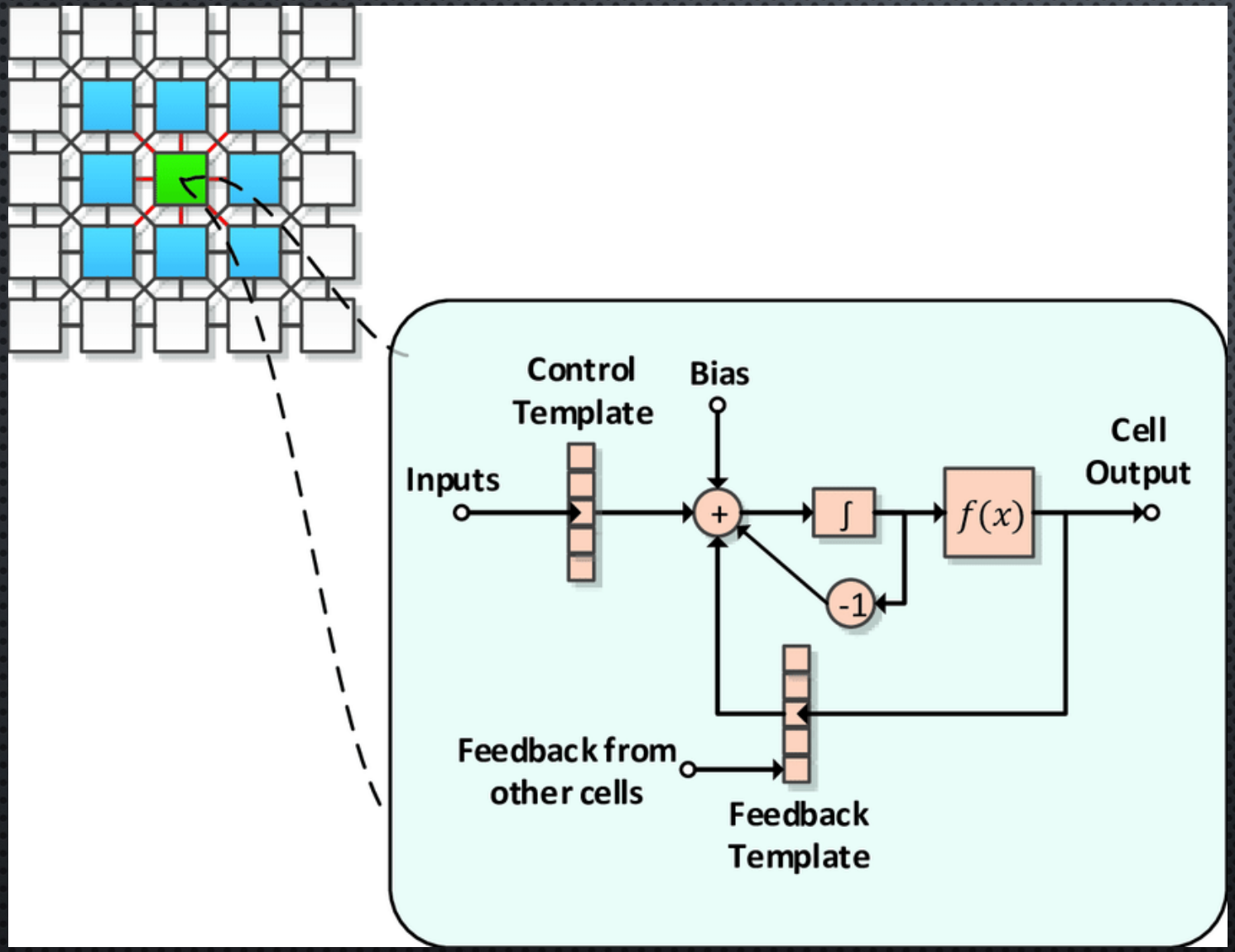
MORPHOGENESIS OF TERMITE MOUNDS, PNAS, 2019



COLLECTIVE INTELLIGENCE

- Cellular automata
- If a living cell is too isolated (0 or 1 neighbor) then it dies the next evolution (death by under-population).
- If it is reasonably surrounded (2 or 3 neighbors) then it remains alive, but what if it is surrounded by too many cells (4 or more neighbors) it dies to the next generation (death by over-population).
- A cell can also become a live cell if a dead cell is surrounded by three living cells, then it becomes alive (birth by reproduction).

https://www.dcode.fr/game-of-life

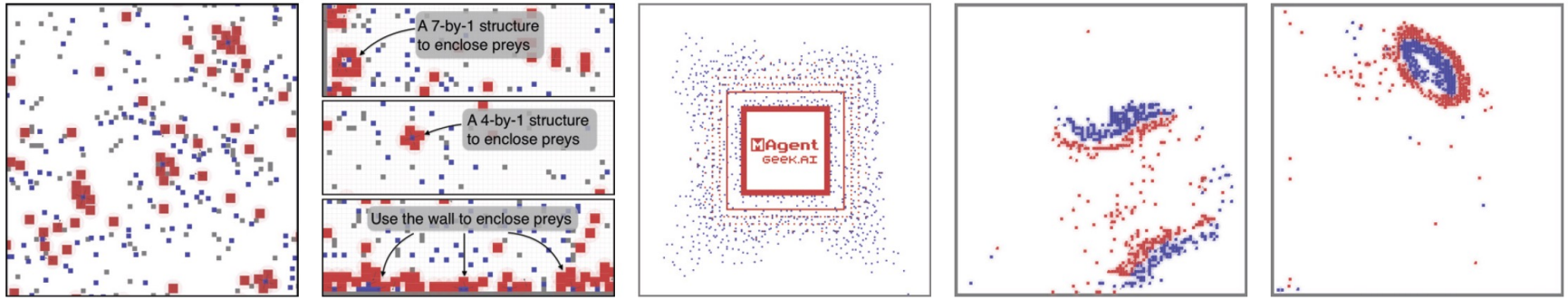


COLLECTIVE INTELLIGENCE

- CELLULAR NEURAL NETWORKS
- INSPIRATIONS FOR NOVEL DEEP LEARNING ALGORITHMS
- *COLLECTIVE INTELLIGENCE FOR DEEP LEARNING: A SURVEY OF RECENT DEVELOPMENTS*

SOFT RADIAL BASIS CELLULAR NEURAL NETWORK (SRB-CNN) BASED ROBUST LOW-COST TRUCK DETECTION USING A SINGLE PRESENCE DETECTION SENSOR, 2016

COLLECTIVE INTELLIGENCE



(a) Pursuit (1) (b) Pursuit (2) (c) Gathering (d) Battle (1) (e) Battle (2)

- Grid world
- Millions of agents
- Evolution of co-operation, competition, altruism and other strategies

MAGENT: A MANY-AGENT REINFORCEMENT LEARNING PLATFORM FOR ARTIFICIAL COLLECTIVE INTELLIGENCE, 2018

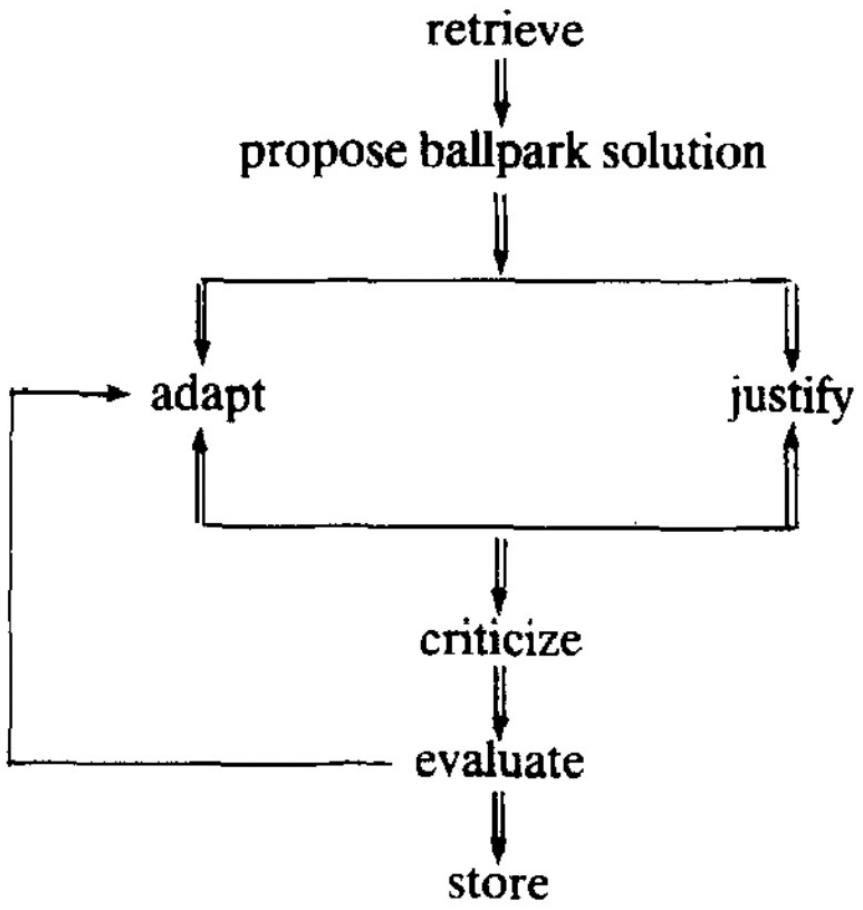


Fig. 1. The case-based reasoning cycle.

CASE BASED REASONING

- How humans reason
  - Doctors, lawyers, …

AN INTRODUCTION TO CASE BASED REASONING, JANET KOLODNER, 1992

APPROACHES

- Dreams
  - Aid generalization and prevent overfitting
- Commonsense reasoning (Davis, Marcus)

EXPLAINABILITY

- Explainability (insights from social sciences)
  - Miller, 2019
- How do you generate explainable models by working with domain experts
  - Rudin, 2019
  - Important for high stakes decisions in domains like healthcare, recidivism prediction

- How can we take inspiration from all these approaches and develop new xAI techniques?

RESOURCES

- HTTPS://GITHUB.COM/NEELSOUMYA/SPECIAL_TOPICS_UNCONVENTIONAL_AI

ADMINISTRIVIA

- PRESENTATIONS
  - Present and lead a discussion on one of these papers (or any other related paper: come speak with me).
  - The idea is that you raise some interesting questions.
  - This course is meant to teach you research skills (like thinking critically about a paper, literature review skills, writing).
  - 15 min presentation, 15 min Q&A

ADMINISTRIVIA

- WRITEUP/REPORT
  - ON THE PAPER YOU PRESENT, AND THE TOPIC IN GENERAL (UNCONVENTIONAL AI).
  - DO A LITERATURE REVIEW OF OTHER PAPERS IN THE FIELD.
  - REFLECT/WRITE ON HOW THESE TECHNIQUES CAN BE INCORPORATED IN MODERN AI/DEEP LEARNING.
  - THE INTENTION IS FOR YOU TO
    - LEARN HOW TO READ PAPERS
    - COMPARE AND CONTRAST THEM TO OTHER PAPERS
    - THEN THINK WHAT THIS MEANS FOR MODERN AI/DEEP LEARNING.
  - ***SHOW ME EARLY DRAFTS***

ADMINISTRIVIA

- WRITEUP/REPORT
  - Short report (less than 4000 words). The idea is to write a coherent narrative.
  - Suggest how these ideas can be incorporated in modern AI/deep learning systems
  - Why do you think these ideas were not successful in the 1950s/1960s?
  - What kind of data would we need to ensure these techniques would work today?
  - What lessons can we learn from the history of AI, what approaches worked and did not work in the past?
  - What could be the disadvantages of these approaches?
  - Rational reconstruction (analytical literature review/survey) of a research area
- Other thoughts on the writeup
  - A detailed research proposal with some ground work already accomplished

ADMINISTRIVIA

- HOW TO READ PAPERS
  - https://www.cs197.seas.harvard.edu/
  - https://docs.google.com/document/d/1bPhwNdCCKkm1_adD0rx1YV6r2JG98qYmTxutT5gdAdQ/edit#heading=h.yxlvj6bo3y2
  - Read widely and then focus on a few papers
  - Take multiple passes through papers

ADMINISTRIVIA

- HOW TO WRITE
  - WRITE REGULARLY
  - SCHEDULE TIME FOR WRITNG
  - https://sites.google.com/site/neelsoumya/research-resources/scientific-writing
  - https://www.youtube.com/watch?v=DeVjXINr5Wk
  - Book on writing (contact me to borrow a copy)
    - *How to write a lot: a guide to productive academic writing* (Paul Silvia)
  - Pick a paper now and start writing your thoughts

ADMINISTRIVIA

- PICK PAPERS AND ASSIGNED READING
  - DATES AND NAMES
  - WE ALL READ PAPERS BEFORE THE CLASS
  - CLASS PARTICIPATION
    - PREPARE A QUESTION BEFOREHAND

3. Perceiving the Bull

I hear the song of the nightingale.
The sun is warm, the wind is mild,
willows are green along the shore
-
Here no Ox can hide!
What artist can draw that massive head,
those majestic horns?[web 8]

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