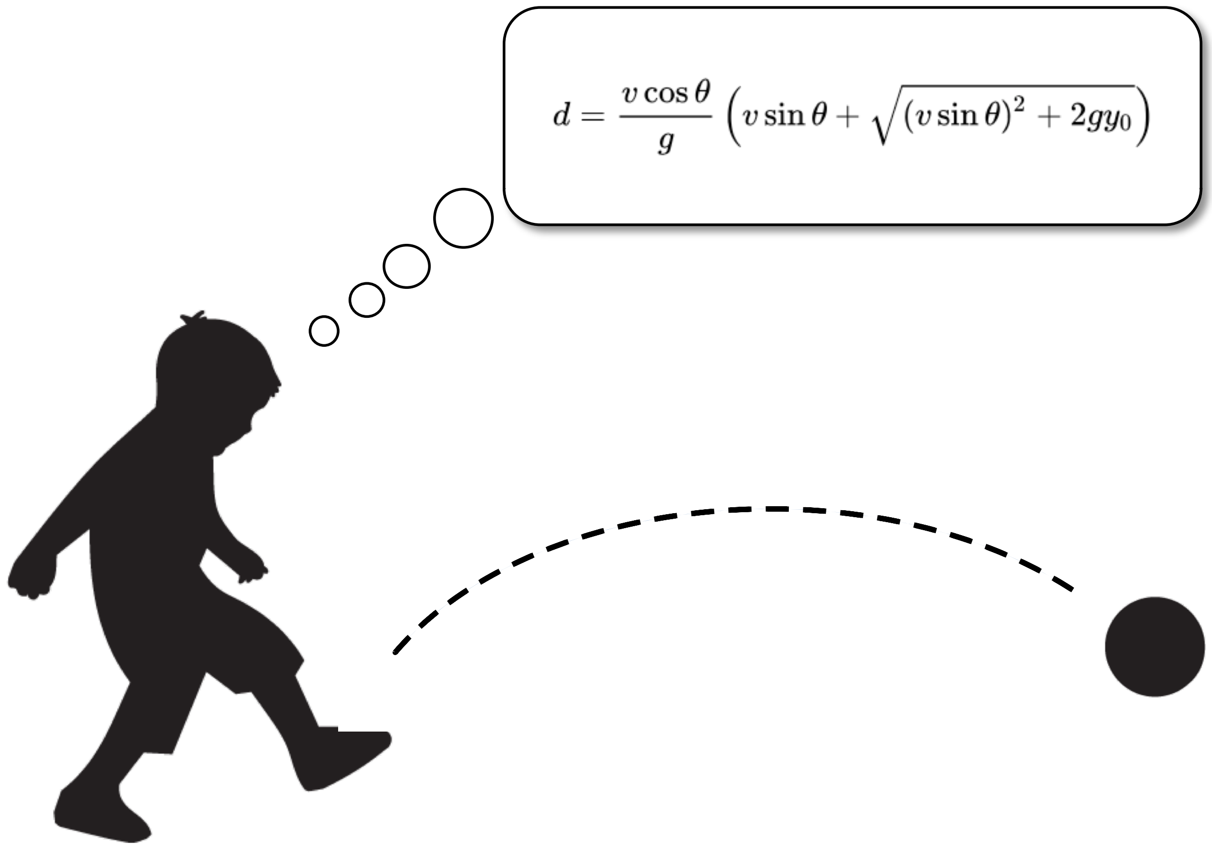
Course: Common Sense Reasoning

4. Physical Reasoning

Martin Molina

We don’t need to think in mathematical equations to perform physical activities



Physical reasoning simulates how someone reasons about the physical world

- In contrast to simulating the world, physical reasoning simulates how an agent reasons about the world

- Physical reasoning does not look for high degree of numerical precision

Physical reasoning and scientific computing have different goals

[Davis 2008]

Physical Reasoning

- Output:
  - Alternative directions of inference (future to past, etc.)
  - Generate explanations
- Precision:
  - Qualitative descriptions that not require exact information.
  - Robust under variation of shape and motion.
- Scale:
  - Everyday domain at the human scale
- Correctness:
  - Psychological plausible theories
  - Not necessarily scientifically correct

Scientific Computing

- Output:
  - The output is a precise prediction
- Precision:
  - High degree of numerical accuracy.
  - Precise parameters (shapes, material properties, initial state, etc)
- Scale:
  - Domains that are highly specialized (very small or very large)
- Correctness:
  - Use theories that are scientifically correct

Naïve physics

Patrick John Hayes
Researcher in Computer Science
Institute for Human and Machine Cognition, Florida
"The Naïve Physics Manifesto" (1978)

Ernest Davis
Professor in Computer Science
New York University
"The naïve physics perplex" (1998)

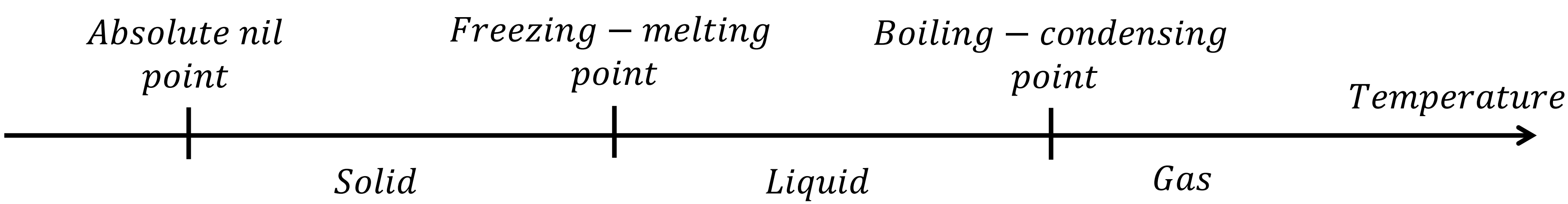
Physical reasoning uses qualitative descriptions

Magnitude: $T \in \{Solid, Liquid, Gas\}$

Derivative: $\partial T \in \{+, 0, -\}$

Examples: $T = Solid$

$\partial T = +$



Qualitative reasoning can be viewed as a constraint satisfaction problem

[Struss 1997]

Constraints
$$\begin{cases} \partial A + \partial B = \partial C \\ \partial A * \partial D = \partial E + \partial F \end{cases}$$

$$\partial X \in \{+, 0, -\}$$

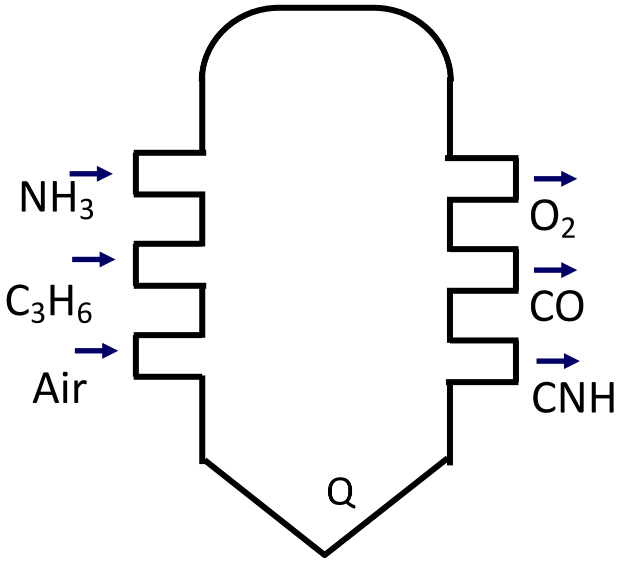
Addition

$+$	$+$	0	$-$
$+$	$+$	$+$	
0	$+$	0	$+$
$-$		$-$	$-$

Multiplication

$*$	$+$	0	$-$
$+$	$+$	0	$-$
0	0	0	$+$
$-$	$-$	0	$+$

Example: Chemical reactor



Variables:

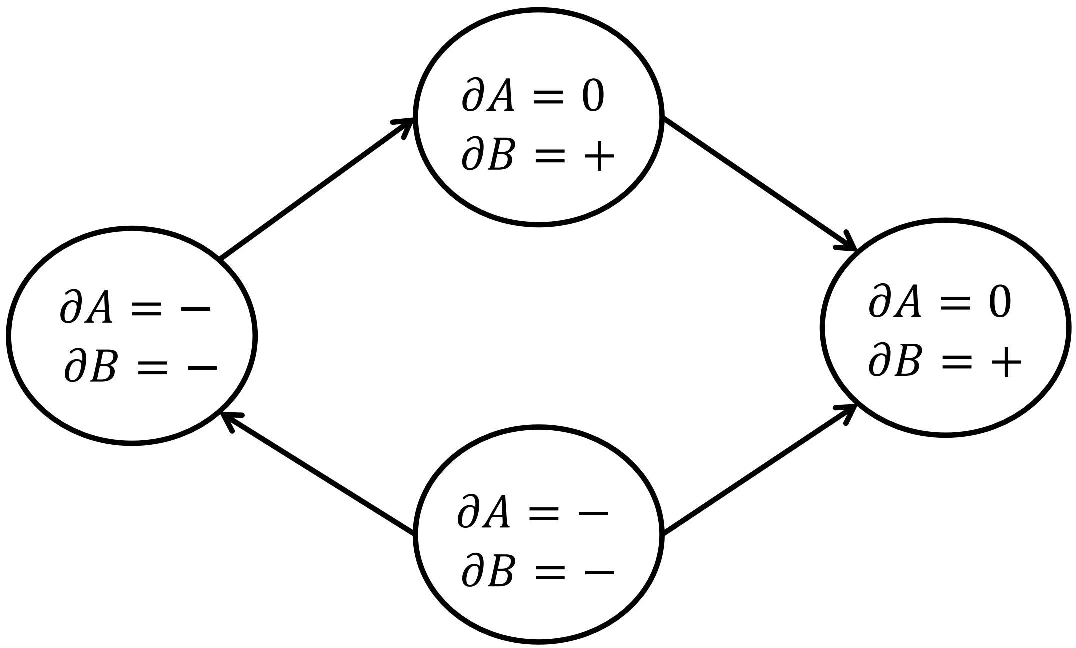
Tendency of ammonia:	dNH3	{+,0,-}
Tendency of propylene:	dC3H6	{+,0,-}
Tendency of air:	dAire	{+,0,-}
Tendency of temperature:	dQ	{+,0,-}
Tendency of oxygen:	dO2	{+,0,-}
Tendency of carbon monoxide:	dCO	{+,0,-}
Tendency of cyanide:	dCNH	{+,0,-}

Constraints:

- R1: dO2 = dAir + dNH3
- R2: dCNH = dAir - dC3H6
- R3: dCO = dC3H6 - dNH3
- R4: dQ = dAir * dNH3

A qualitative reasoning engine produces a state-graph

- State: Set of qualitative values of relevant quantities
- Transition: How one state may change into another state



There are multiple approaches for qualitative reasoning

[Weld, de Kleer, 1990]

- Component-based approach (De Kleer and Brown, 1984)
  - Components (e.g, water tanks) that manipulate materials (water, electrons) and conduits that transport materials.
- Process-based approach (Forbus, 1984)
  - Processes describe mechanisms of change. These changes are represented by influences.
- Constraint-based approach (Kuipers, 1986)
  - Ordinary differential equations (ODE's) are rewritten into qualitative differential equations (QDE's) for qualitative simulation.

Johan de Kleer
Manager of the Systems and Practices Laboratory Palo Alto Research Center (PARC)
The NEWTON program (1977)

Kenneth Forbus
Professor of Computer Science
Northwestern University, Illinois
The FROB program (1980)

https://ivi.fnwi.uva.nl/tcs/QRgroup/QRM//

Qualitative Reasoning & Modelling

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Introduction

The Qualitative Reasoning and Modelling (QRM) portal provides software tools (Garp3), documentation and support for users to build and simulate qualitative models. Qualitative Reasoning (QR) is an area of research within Artificial Intelligence (AI) that automates reasoning and problem solving about the (physical) world. It creates non-numerical descriptions of systems and their behaviour, preserving important behavioural properties and qualitative distinctions. Successful application areas include autonomous spacecraft support, failure analysis and on-board diagnosis of vehicle systems, automated generation of control software for photocopiers, conceptual knowledge capture in ecology, and intelligent aids for human learning (Bredeweg & Struss, 2003).

Qualitative Reasoning has particularly value for developing, strengthening and further improving education and training on topics dealing with systems and their behaviour. The goal of this QRM portal is to provide tools, methods and communication facilities to support such activities. Particularly the Garp3 workbench is being developed to support users in articulating, simulating and inspecting their conceptual knowledge of system's behaviour. See Software for the latest version of Garp3.

Selected publications

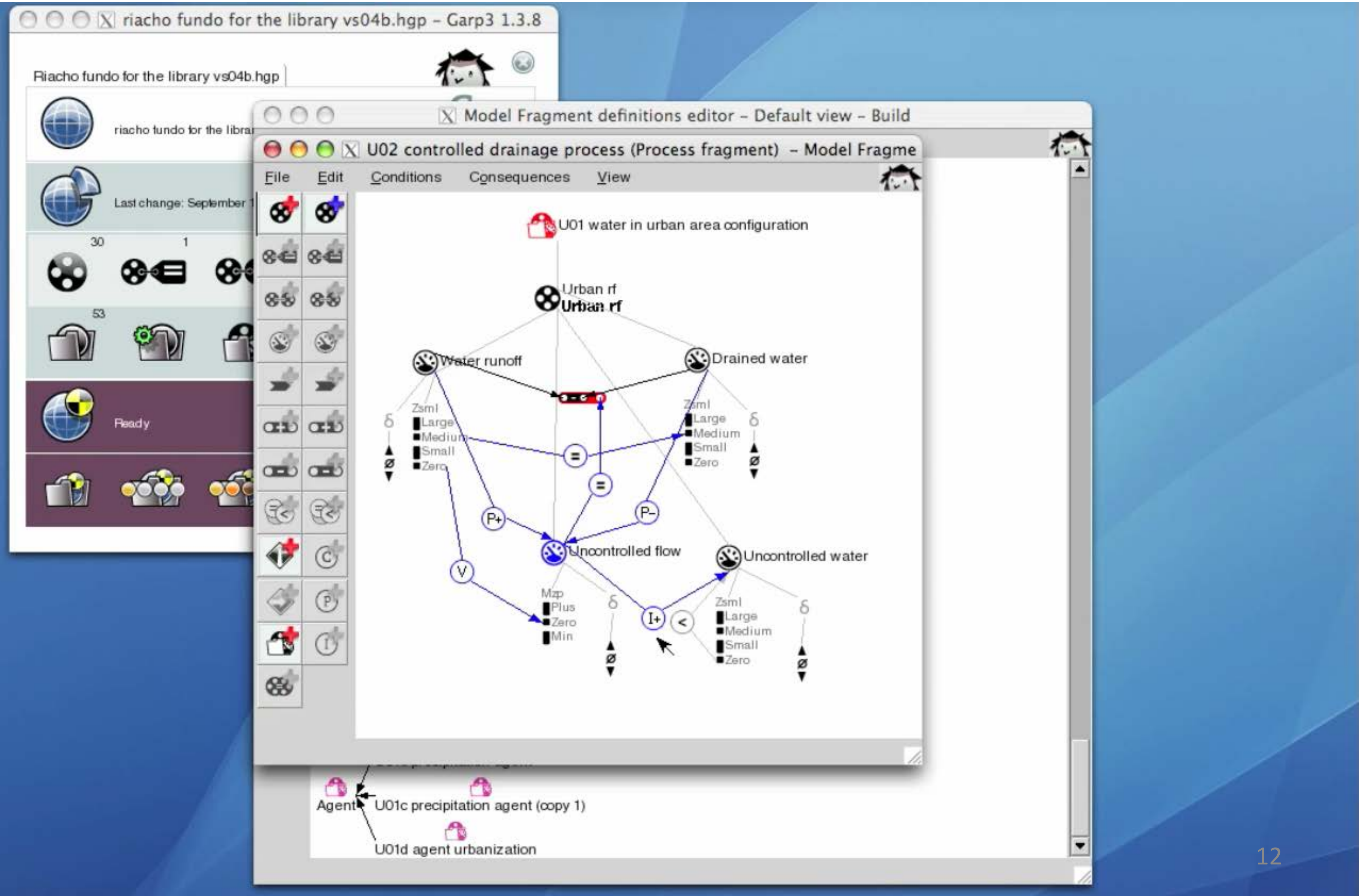
- Bredeweg, B., Linnebank, F., Bouwer, A., and Liem, J., 2009. Garp3 - Workbench for Qualitative Modelling and Simulation. Ecological Informatics 4(5-6), 263-281.
- Bredeweg, B., Salles, P., 2009. Mediating conceptual knowledge using qualitative reasoning. In: Jrgensen, S.V., Chon, T-S., Recknagel, F.A. (Eds.), Handbook of Ecological Modelling and Informatics. Wit Press, Southampton, UK, pp. 351-398.
- Special issue of the International Journal Ecological informatics on Qualitative models of ecological systems, 4(5-6), 261-412, December 2009

Garp 3

Movie Demo

Watch or download our movie demonstration (18min/25MB, Quicktime)

Garp3 is a software tool for qualitative reasoning



Micro theories for common sense reasoning

Ernest Davis
Professor in
Computer Science
New York University

Liquids

"Pouring liquids: A study in commonsense physical reasoning", *Artificial Intelligence*, 2008.

Boxes

"How does a box work? A study in the qualitative dynamics of solid objects", *Artificial Intelligence*, 2010.

Course “Common sense reasoning”.
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Work citation in APA style:

Molina, M. (2019). Common sense reasoning [Lecture slides]. OpenCourseWare, Universidad Politécnica de Madrid. Retrieved from http://ocw.upm.es/course