Knowledge Representation and Reasoning

Part 1: Introduction

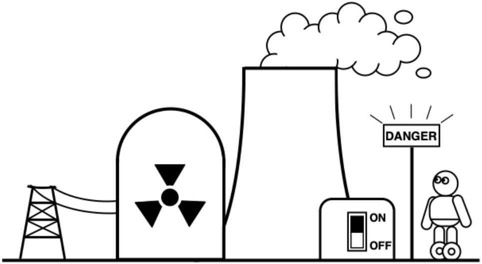
Ivan Varzinczak

LIASD, Université Paris 8, France

https://www.ijv.ovh

Motivation

Example of a basic epistemic scenario



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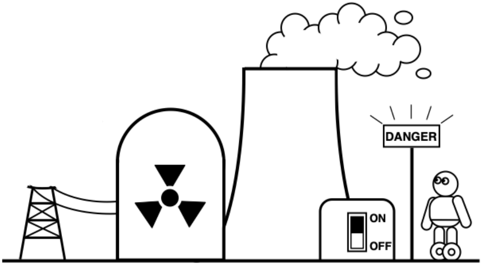

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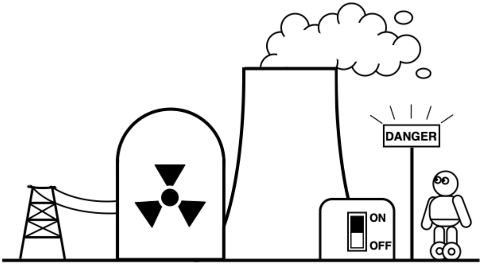

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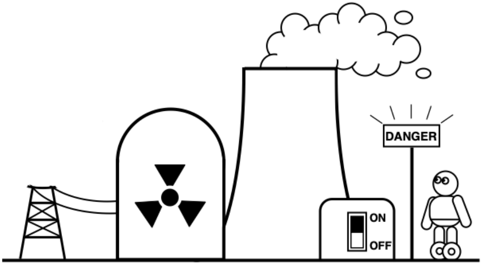

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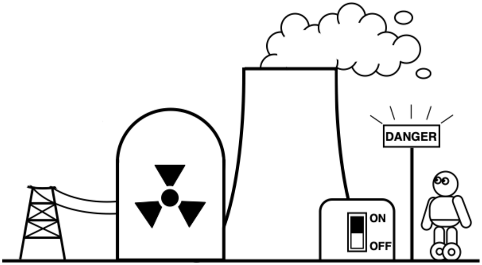

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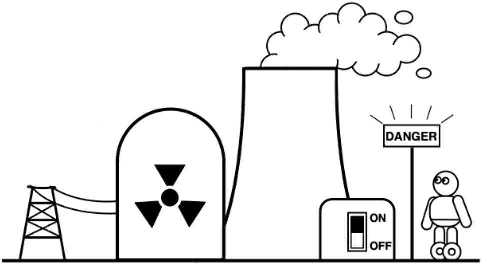

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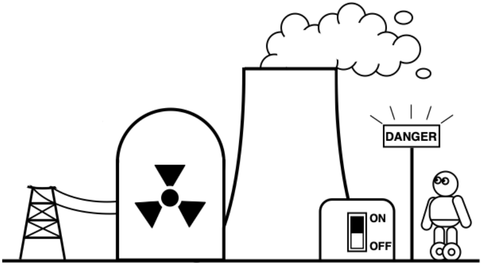

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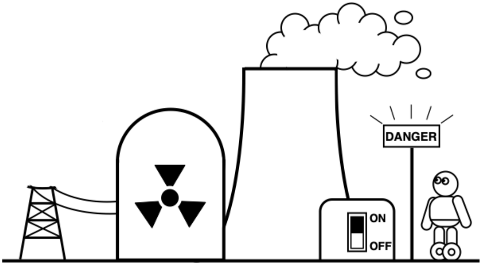

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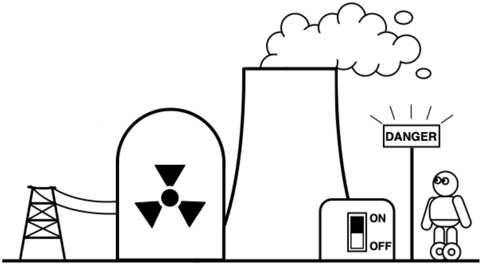

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- Why does the agent want to know the state of the system? Safety!
- Can the agent know everything about the system by observation?
- What else is needed? Knowledge! What else is useful? Common sense!

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- The system
- The incomplete information
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- How to extract more information from the system? By reasoning!

Outline

Representations

Semantics

Symbolic representation

Truth

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Symbolic representation

Truth

What is an agent?

Artificial agents

- Software: a spell-checker, a chatbot, ...
- Hardware: a thermostat, a fire alarm, ...
- Both: a robot, a self-driving car, ...

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Agent's behaviour

- Identification of a pattern
- Actions taken by an agent need to bear some relation to its environment
- Ability to adapt in response to the environment
- Supposed to be rational

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Responsiveness to the environment

- Achieved via an internal representation of the environment
- The representation is a substitute for the real system
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Varieties of agents

- Simplest agents: only iconic representations
- More complex agents: both iconic and symbolic representations

Iconic v. symbolic representations

Iconic representation

- Somehow directly resembles or mimics the external system
- More concrete
- E.g. a person's photograph, a map, a model aeroplane in a wind tunnel
- The model resembles the real thing in those aspects considered relevant

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Symbolic representation

- The resemblance with the environment is indirect or conventional
- More abstract
- Usually a description in some language
- E.g. a person's name, a description of a system in some language
- But not always: a wedding ring is a symbol of a mutual agreement

Iconic v. symbolic representations

In this module

- We are concerned with agents that also have a symbolic representation
- We assume agents have access to a symbolic language

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Importance of language

- Communication between agents fostering cooperative behaviour
- It is discrete, easing its processing and storage
- It can be mapped into an iconic representation, its semantics
- It lends itself naturally to verification and explanation

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We are at the designer's level

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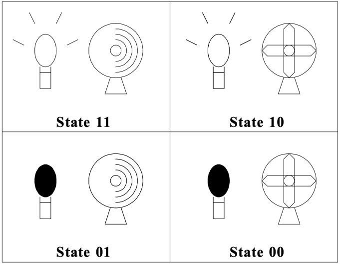

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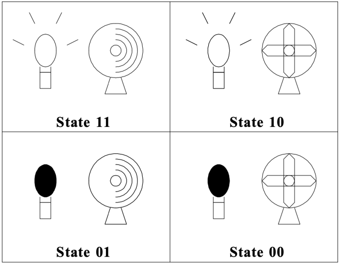

What information can an agent extract from the system via its sensors?

Phases of information gathering

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Default rule

- Finally, the agent may bring to bear a default rule
- These correspond to heuristics, statistical data, or commonsense
- Exclusion of 0 or more states leading to $C_{\mathsf{fed}} \subseteq \mathcal{S}$

Phases of information gathering

Example (Light-fan system)

Candidate states to be the actual state: $\mathcal{S} = \{00, 01, 10, 11\}$

1. "The fan is never on when the light is off": $C_{\mathsf{f}} = \{00, 10, 11\}$
2. The agent sees the light is on: $C_{\mathsf{fe}} = \{10, 11\}$
3. "When the light is on, then usually the fan is on": $C_{\mathsf{fed}} = \{11\}$

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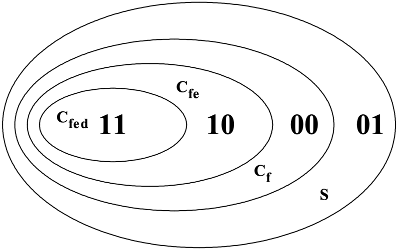

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A knowledge-representation language

Representing facts

- The state of the system is completely determined by its basic facts
- E.g. whether the light is on and whether the fan is on
- With $\mathcal{P}$ we denote a set of propositional atoms
- E.g. $\mathcal{P} = \{p, q\}$, where $p =$"the light is on" and $q =$"the fan is on"

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What about more complex claims?

- Equip the language with connectives

$\neg$	(negation)	$\rightarrow$	(conditional)
$\wedge$	(conjunction)	$\leftrightarrow$	(biconditional)
$\vee$	(disjunction)		

- Build complex sentences from atoms and connectives

A knowledge-representation language

Let α and β be sentences

- $\neg\alpha$ is read "not α"
- $\alpha \land \beta$ is read "α and β"
- $\alpha \lor \beta$ is read "α or β (or both)"
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Some remarks

- In $\alpha \wedge \beta$, we call α, β the conjuncts
- In $\alpha \vee \beta$, we call α, β the disjuncts
- In $\alpha \rightarrow \beta$, α is the antecedent and β the consequent

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- We put ourselves as external observers to the system
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A sentence α only has a truth value relative to a given state

Semantics of sentences

Compositionality

α	$\neg\alpha$
1	0
0	1

α	β	$\alpha \land \beta$
0	0	0
0	1	0
1	0	0
1	1	1

α	β	$\alpha \lor \beta$
0	0	0
0	1	1
1	0	1
1	1	1

α	β	$\alpha \to \beta$
0	0	1
0	1	1
1	0	0
1	1	1

α	β	$\alpha \leftrightarrow \beta$
0	0	1
0	1	0
1	0	0
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Epilogue

Summary

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- Different types of representation: iconic and symbolic
- The phases of information gathering
- The foundations of a representation language
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What next?

- Opaque representation languages
- Semantic foundations of reasoning