Logic-Based Agents[1]

Lecture 1

[1] The slides have been prepared using the textbook material available on the web, and the slides of the previous editions of the course by Prof. Luigia Carlucci Aiello

Summary

- ♢ Logical Agents   Russell & Norvig Sect. 7.1–7.3
- ♢ Knowledge Representation
- ♢ Knowledge-based Agents
- ♢ The wumpus world
- ♢ Models and Inference

Symbol hypothesis

The conputer belongs to a class of artificial systems, **symbolic systems**...

Symbols can be used to represent **structures**. . . .

A computer is a symbolic system, where symbols are **created, modified, copied,**. . .

not a quote, but this is argued in:
[H. Simon, The Sciences of the Artificial, 1969, 1994]

Properties of a good representation

A **representation** is made by a set of symbols, stored on a computer together with algorithms that allow to us to use it in order to solve problems.

◇ **Adequacy** criteria by McCarthy & Hayes in 1969: **metaphysics, epistemology, heuristics**

◇ language expressive power (ontology)

◇ level of abstraction

◇ good design (computation)

Representation language

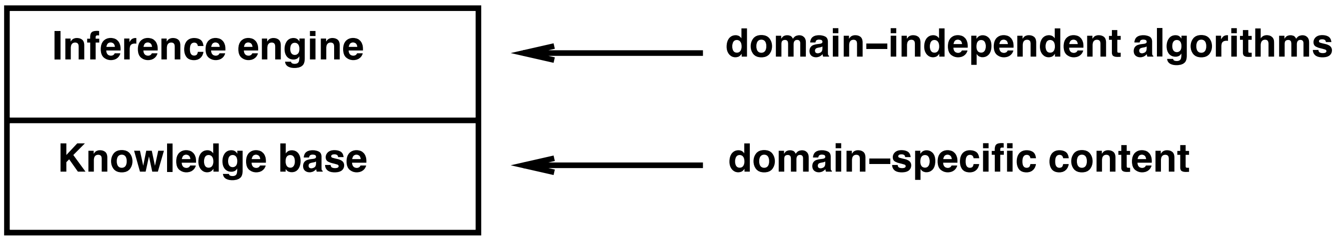
- not a programming language
- not a communication language

Propositional Logic is the basic example:

Key principle: syntax – semantics – reasoning

Possibly "visual", but semantically well defined

Knowledge bases



In a knowledge representation language the set of inferences is defined without referring to the algorithm to compute them.

Knowledge bases

Knowledge base = set of sentences in a formal language

Declarative approach to building an agent (or other system):
TELL it what it needs to know

Then ASK it what to do—answers that follow from the KB

Agents can be viewed at the knowledge level
i.e., what they know, regardless of how implemented

Or at the implementation level
i.e., data structures in KB and algorithms that manipulate them

An example

knowledge base	inference
Rain Wind if Rain then TakeUmbrella if Wind then WindJacket if Rain and WithoutUmbrella then Wet	when the kb contains A and if A then B, B can be derived

From the knowledge base:

Rain??

Wind??

TakeUmbrella??

WindJacket??

Fog??

Wet??

A simple knowledge-based agent

function KB-AGENT(*percept*) **returns** an *action*
  static: KB, a knowledge base
      t, a counter, initially 0, indicating time

  TELL(KB, MAKE-PERCEPT-SENTENCE(*percept*, t))
  $action \leftarrow$ ASK(KB, MAKE-ACTION-QUERY(t))
  TELL(KB, MAKE-ACTION-SENTENCE($action$, t))
  $t \leftarrow t + 1$
  return *action*

A simple knowledge-based agent

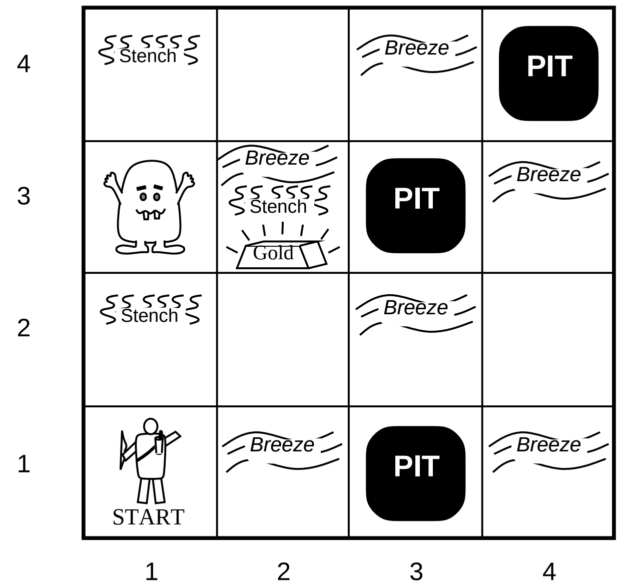
The agent must be able to:

- Represent states, actions, etc.
- Incorporate new percepts
- Update internal representations of the world
- Deduce hidden properties of the world
- Deduce appropriate actions

Wumpus World PEAS description

Environment

Squares adjacent to wumpus are smelly
Squares adjacent to pits are breezy
Glitter iff gold is in the same square
Shooting kills wumpus if you are facing it
Shooting uses up the only arrow
Grabbing picks up gold if in same square
Releasing drops the gold in same square



Notice: the world in RN is symmetric (i.e. $[3,1] \rightarrow [1,3]$)

Wumpus World PEAS description

Performance measure

gold +1000, death -1000
-1 per step, -10 for using the arrow

Sensors

Stench, Breeze, Glitter, Bump, Cry

Actuators

Left turn, Right turn, Forward,
Grab, Release, Shoot

Wumpus world characterization

Observable?? No—only local perception

Deterministic?? Yes—outcomes exactly specified

Episodic?? No—sequential at the level of actions

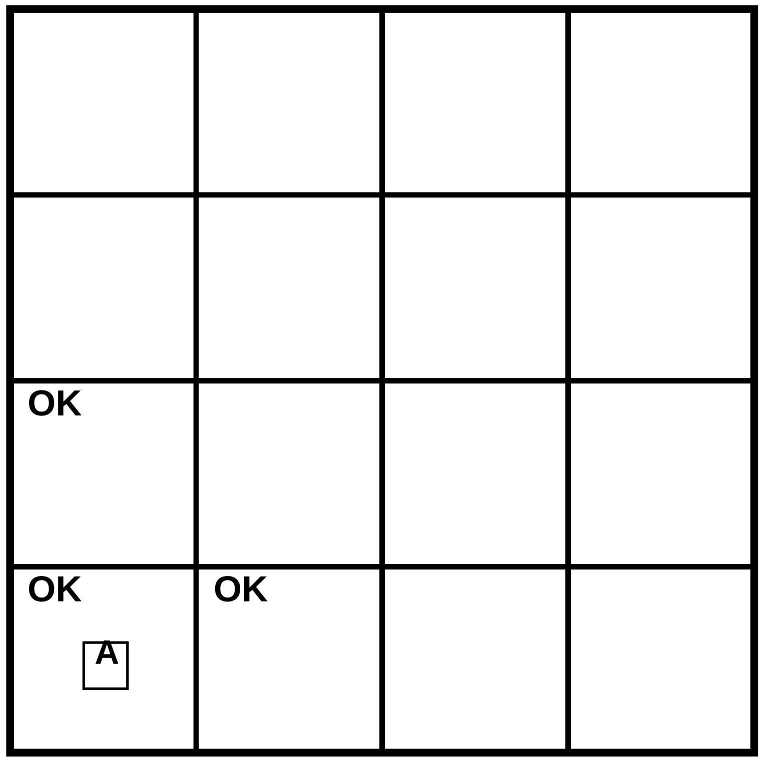
Static?? Yes—Wumpus and Pits do not move

Discrete?? Yes

Single-agent?? Yes—Wumpus is essentially a natural feature

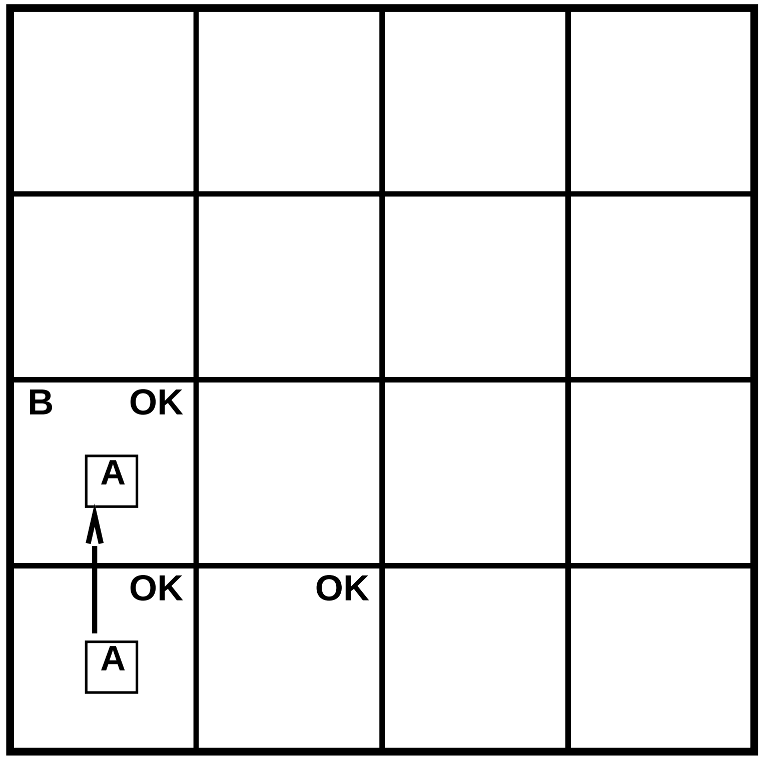
Exploring a wumpus world

Sensors: [None,None,None,None,None]



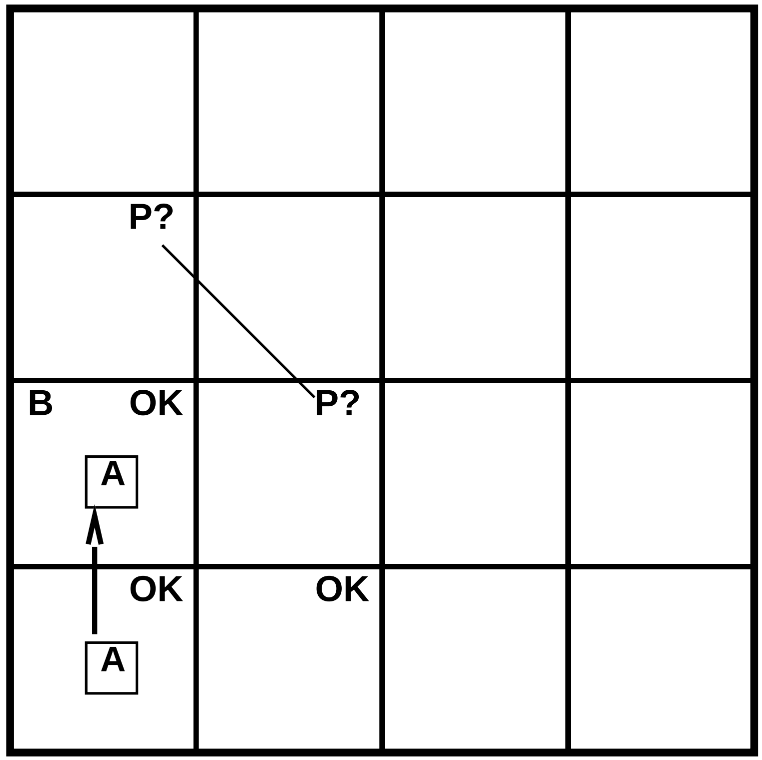
Exploring a wumpus world

Sensors: [None,Breeze,None,None,None]



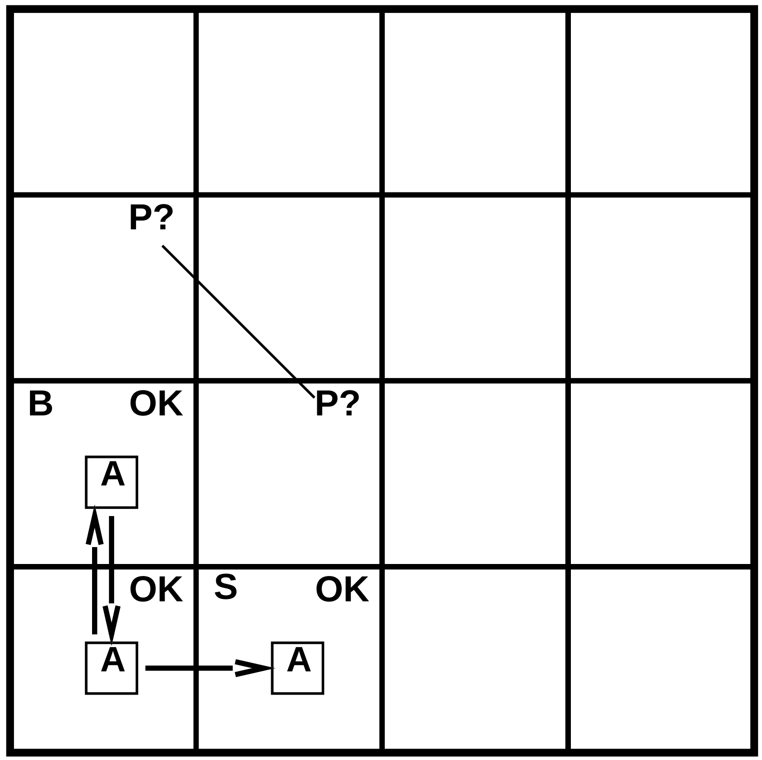
Exploring a wumpus world

Squares adjacent to pits are breezy



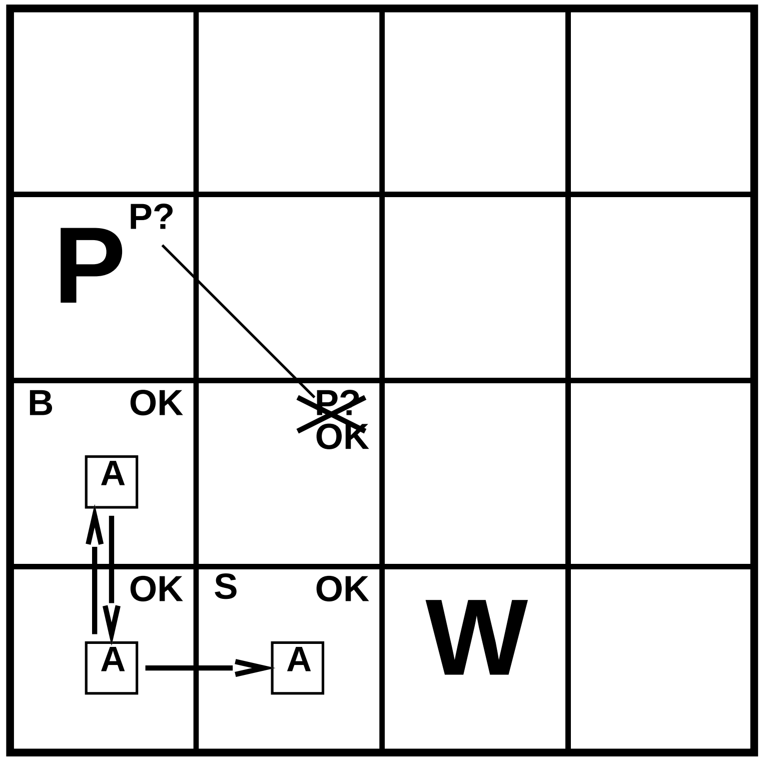
Exploring a wumpus world

Sensors: [Stench,None,None,None,None]

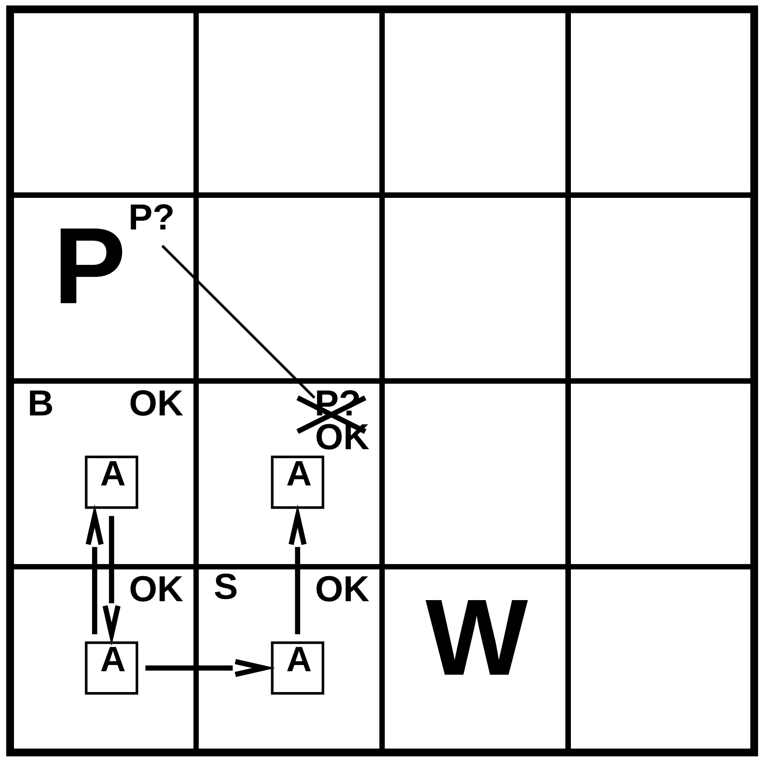


Exploring a wumpus world

Squares adjacent to wumpus are smelly

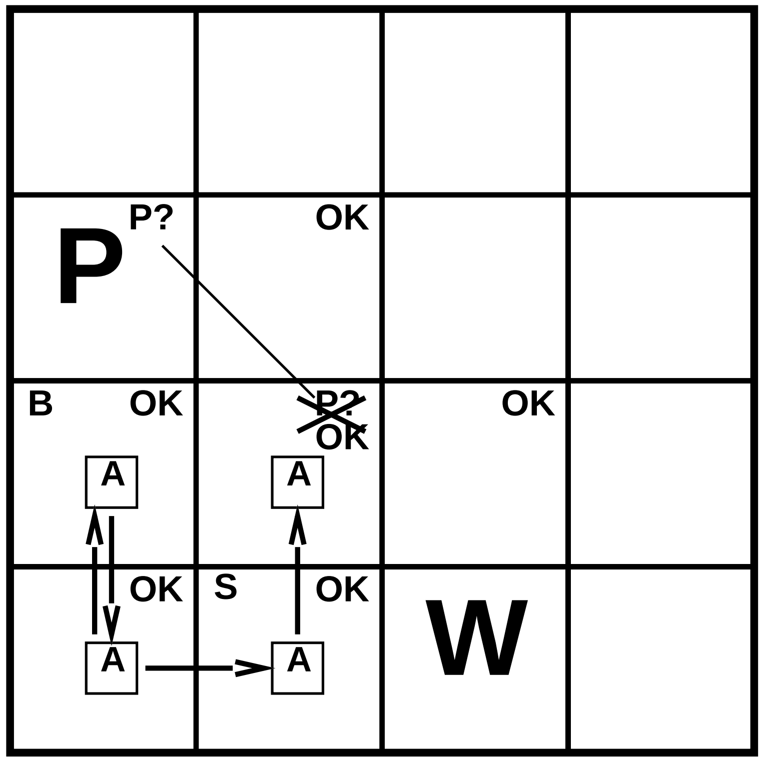


Exploring a wumpus world



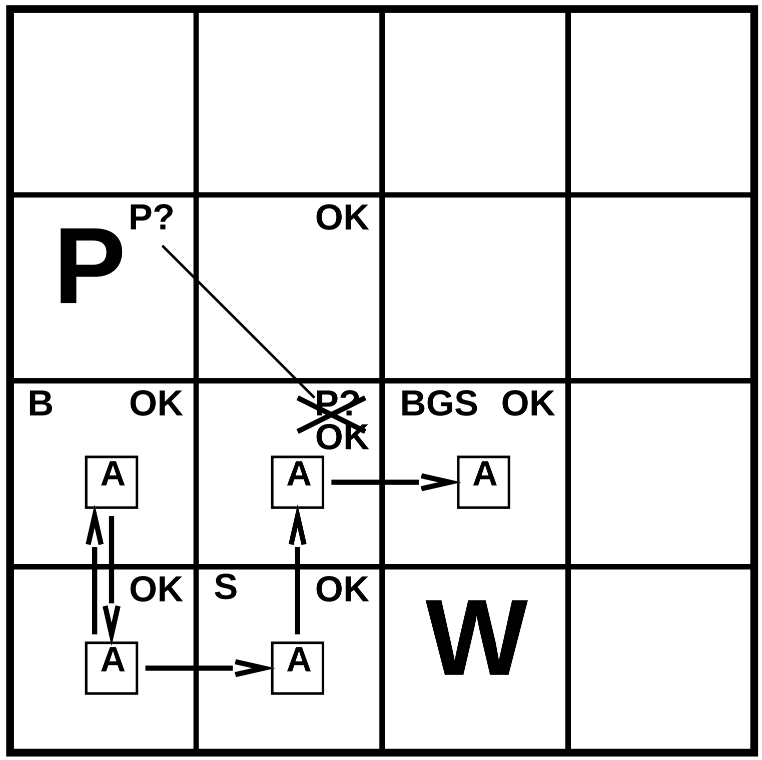
Exploring a wumpus world

Sensors: [None,None,None,None,None]



Exploring a wumpus world

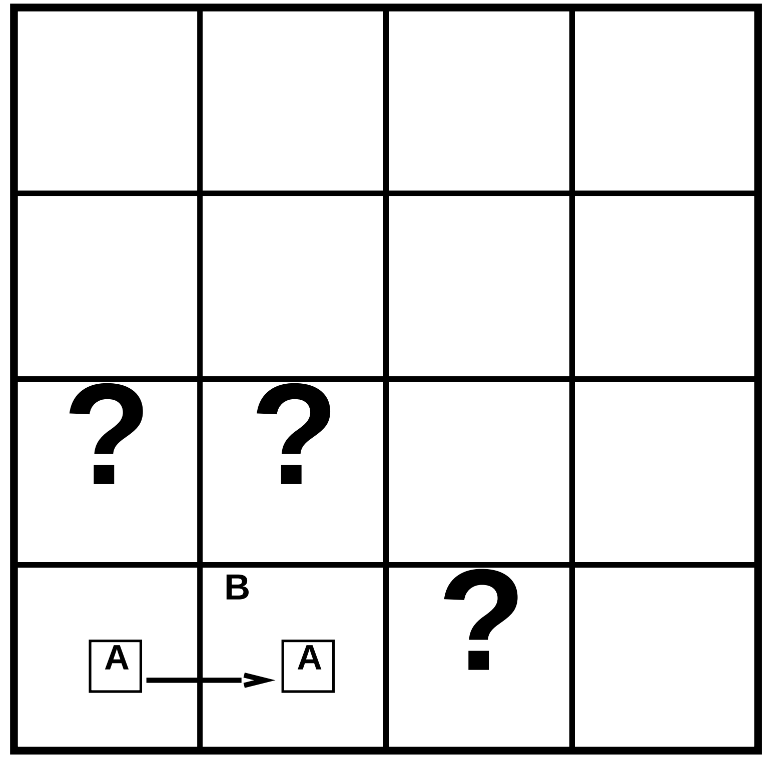
Sensors: [None,None,Glitter,None,None]



Entailment in the wumpus world

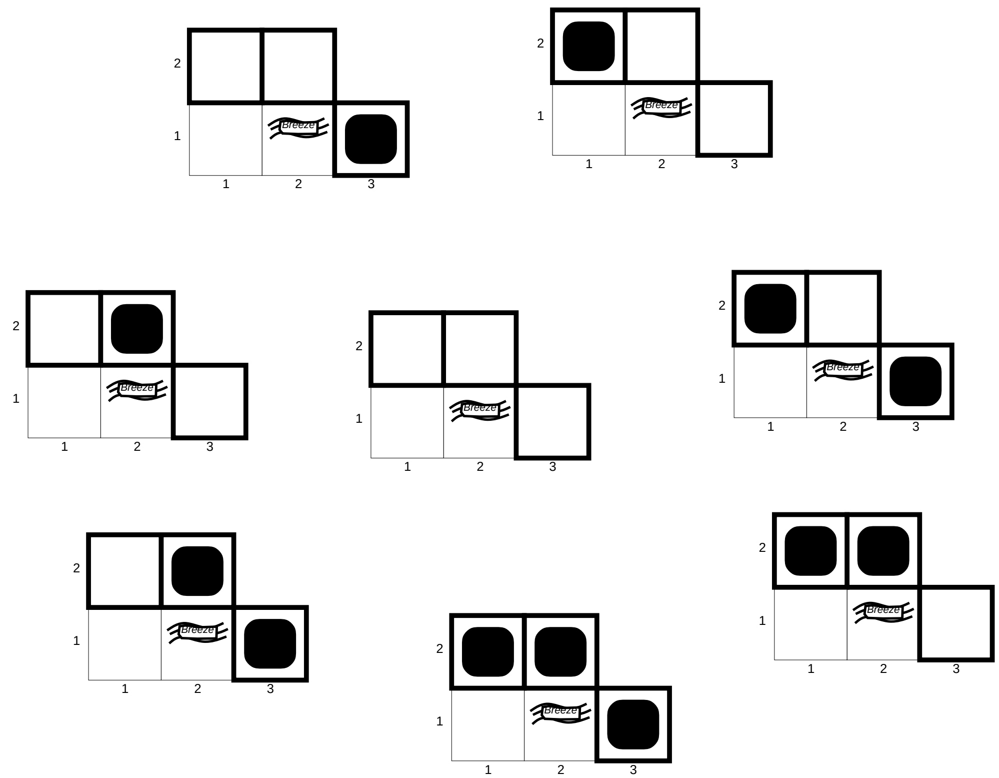
Situation after detecting nothing in [1,1],
moving right, breeze in [1,2]
(Back to RN notation [col,row])

Consider possible cases for ?s assuming only pits

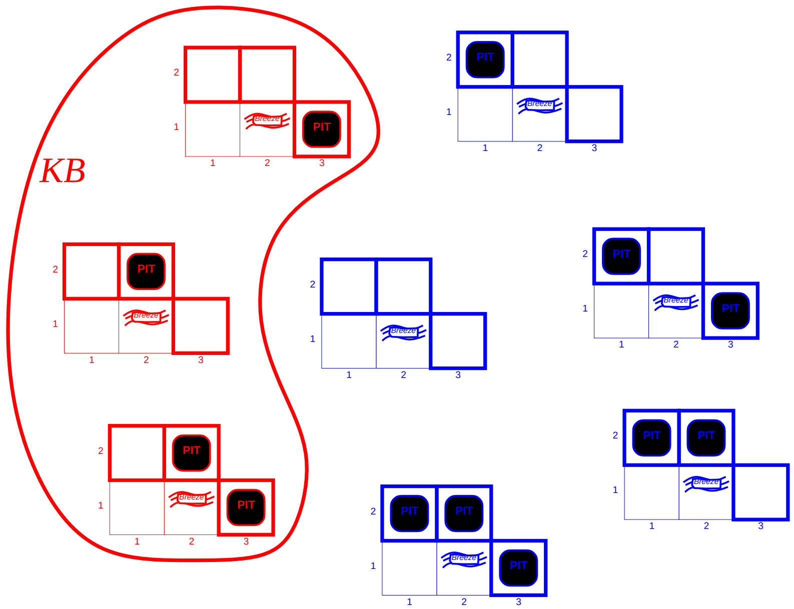


3 choices (8 possible cases) for the presence of pits in [1,2],[2,2],[3,1].

Wumpus possible worlds



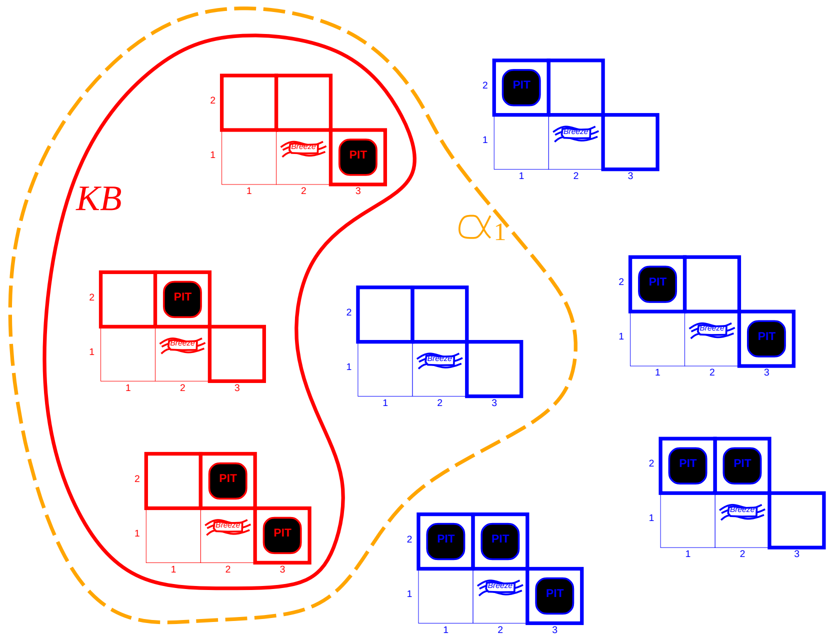
Wumpus models



KB = wumpus-world rules + observation $\neg B[1,1]$ and $B[1,2]$

models = possible worlds that are “coherent with KB

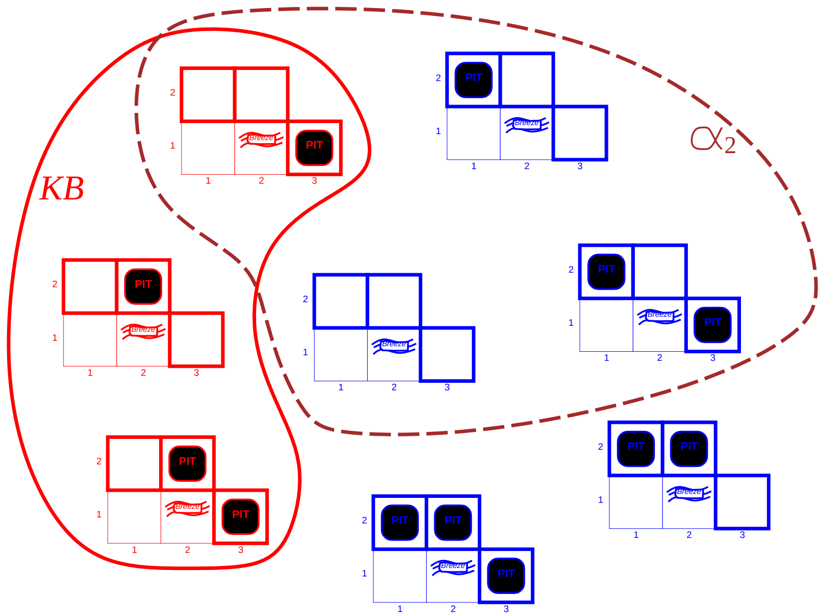
Inference by model checking



KB as before and $\alpha_1 =$ "[1,2] is safe"? – No Pit in [1,2]?

Yes, $KB \models \alpha_1$

Inference by model checking



KB as before and $\alpha_2 =$ "[2,2] is safe"? – No Pit in [2,2]?

No, $KB \not\models \alpha_2$

Logic in general

Logics are formal languages for representing information such that conclusions can be drawn

Syntax defines the legal sentences in the language

Semantics define the "meaning" of sentences;
i.e., define truth of a sentence in a world

E.g., the language of arithmetic

$x + 2 \geq y$ is a sentence; $x2 + y >$ is not a sentence

$x + 2 \geq y$ is true iff number $x + 2$ is no less than number y

$x + 2 \geq y$ is true in a world where $x = 7, \ y = 1$
$x + 2 \geq y$ is false in a world where $x = 0, \ y = 6$

Entailment

Entailment means that one sentence *follows from* another:

$$KB \models \alpha$$

Knowledge base KB entails sentence α
if and only if
α is true in all worlds where KB is true

Entailment is a relationship between sentences (i.e., *syntax*) that is based on *semantics*

Note: brains process *syntax* (of some sort)

Models

Possible worlds correspond to assignments of truth values to the symbols of a sentence, called interpretations.

We say m is a model of a sentence α if m is an interpretation and α is true in m

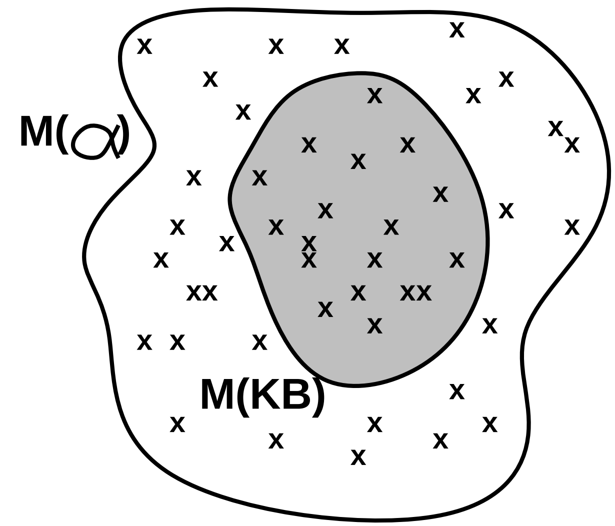
$M(\alpha)$ is the set of all models of α

Then $KB \models \alpha$ if and only if $M(KB) \subseteq M(\alpha)$

NOTE: Russell and Norvig overload the term **model** by using it also for interpretations

Models: example

E.g. $KB =$ Giants won and Reds won
$\alpha =$ Giants won



Model Checking

The knowledge that is entailed by a KB can be computed by:

$$KB \models \alpha$$

can be derived by building models and checking whether:

$$M(KB) \subseteq M(\alpha)$$

This approach is referred to as **model checking**

Deduction

Another way of computing the knowledge entailed by a KB is by a **deduction procedure** (proof):

$$KB \vdash_i \alpha$$

denotes that α can be derived from KB by procedure i

Deduction works on formulae by applying **inference** rules.

Note: the term inference is used for any procedure that can compute logical entailment.

Properties of deduction procedures

Soundness: i is sound if

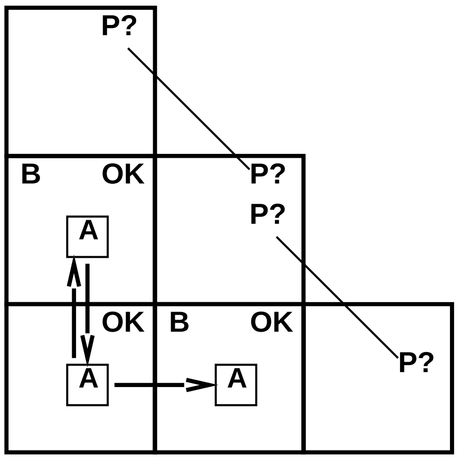
whenever $KB \vdash_i \alpha$, it is also true that $KB \models \alpha$

Completeness: i is complete if

whenever $KB \models \alpha$, it is also true that $KB \vdash_i \alpha$

That is, a sound and complete procedure will answer any question whose answer follows from what is known by the KB.

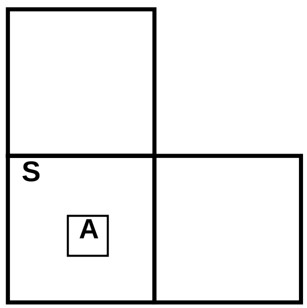
Sometimes there is no certainty



Breeze in (1,2) and (2,1)
$\Rightarrow$ no safe actions

Assuming pits uniformly distributed,
(2,2) has pit w/ prob 0.86, vs. 0.31

Sometimes you can only try



Smell in (1,1)

$\Rightarrow$ cannot move

Can use a strategy of coercion:

shoot straight ahead

wumpus was there $\Rightarrow$ dead $\Rightarrow$ safe

wumpus wasn't there $\Rightarrow$ safe