Cognitive Robotics

Introduction to Cognitive Science

Cool Videos (of course!)

- Rubik's Cube solving robot
- Animal-Inspired Robots
- Big Dog
- Humanoid Robot (Nao)
- Self-Assembling Robots
- Evolutionary Robotics

What is Cognitive Robotics?

- The Cognitive Robotics group is concerned with endowing robotic or software agents with higher level cognitive functions that involve reasoning, for example, about goals, perception, actions, the mental states of other agents, collaborative task execution, etc.

  – University of Toronto Cognitive Robotics group

What is Cognitive Robotics?

- **Cognitive robotics (CR)** is concerned with endowing robots with mammalian and human-like cognitive capabilities to enable the achievement of complex goals in complex environments. Cognitive robotics is focused on using animal cognition as a starting point for the development of robotic computational algorithms, as opposed to more traditional Artificial Intelligence techniques, which may or may not draw upon mammalian and human cognition as an inspiration for algorithm development.

  – Wikipedia

What is Cognitive Robotics?

- Cognitive robotics is a new approach to robot programming based on high level primitives for perception and action. These primitives draw inspiration from ideas in cognitive science

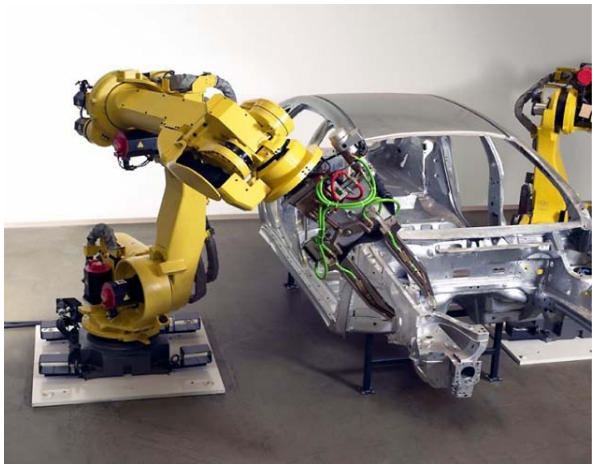
  – CMU's Cognitive Robotics course website

What is Cognitive Robotics?

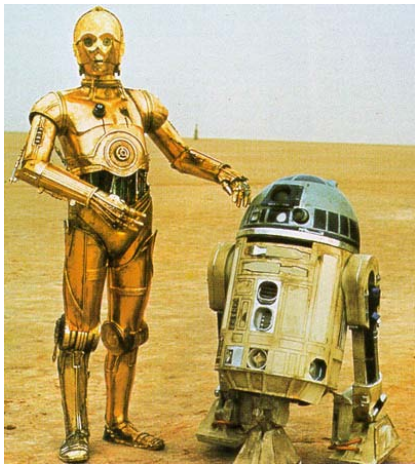
- Robotics + Cognitive Science
  - Create robots with cognitive abilities
  - Create robots that are human-like
- Cognitive Science → Robotics
  - Use cognitive science to improve robots
- Robotics → Cognitive Science
  - Use robots to test cognitive science theories
  - Use robots to compare different cognitive architectures
  - Use robots to identify problems and questions about cognition
  - Use robots as a platform to learn about cognition

Two Kinds of Robots: From a D to a C!

- The ‘Automaton’ Robot
  - 3 D’s: Dull, Dirty, Dangerous
  - One essential D: Dumb!



- The ‘Autonomous’ Robot
  - C’s: Clever, Charismatic, Creative
  - Essential C: Cognitive!



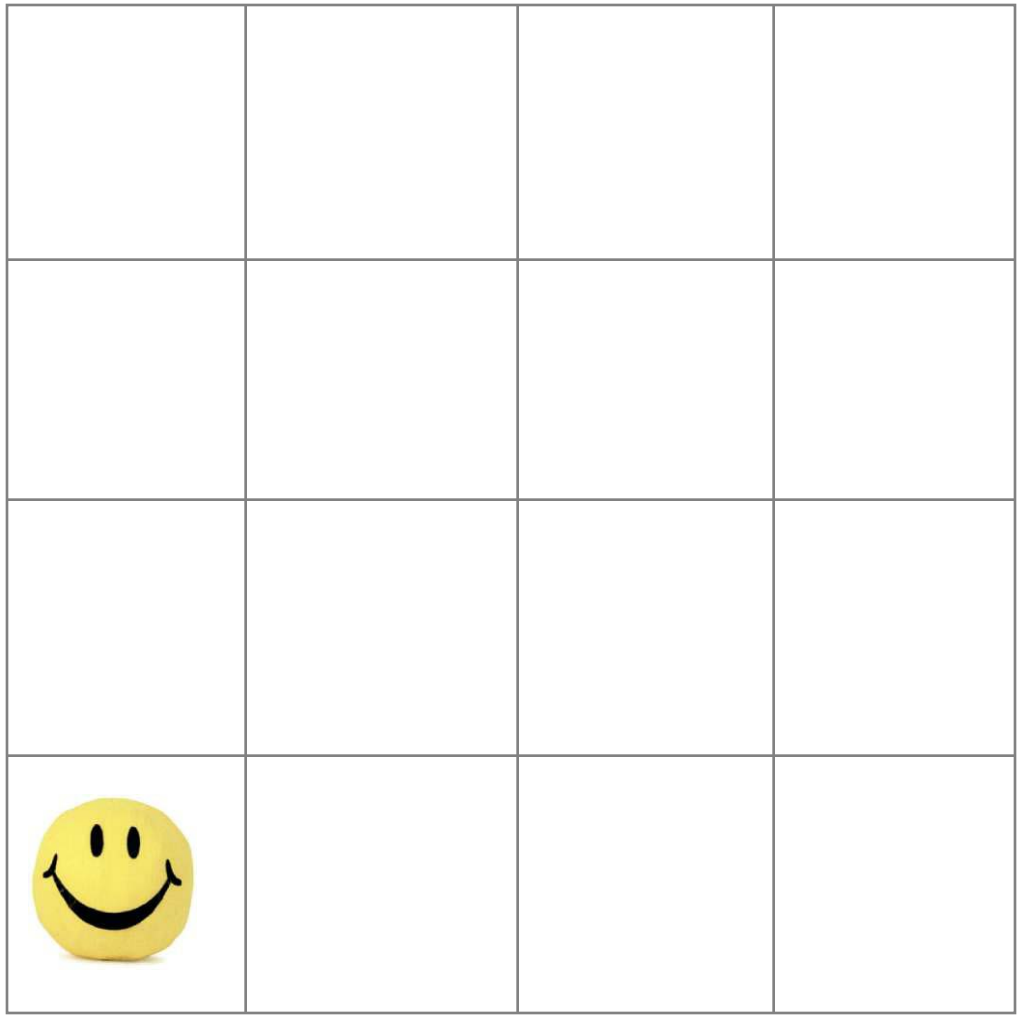
Cognitive Robotics: Robotics + Cognitive Science

- Cognitive Robotics as building robots with cognitive capabilities:
  - High-Level Perception and Action
  - Attention
  - Memory
  - Learning
  - Concept Formation
  - Reasoning and Problem Solving
  - Communication and Use of Language
  - Theory of Mind
  - Social Interaction

LEGObot Competition at RPI
Hunt the Wumpus!

- 11 years running
- Minds & Machines freshmen-only course
- Build cognitive robots using LEGOs and the Handy Board (HC11 microcontroller) to play the game on a physical board
- Game that requires reasoning and planning in order to solve
- 4x4 grid
- Find the gold and get out, while avoiding the wumpus, and multiple pits
- Player is given clues when adjacent to a game object

Hunt the Wumpus



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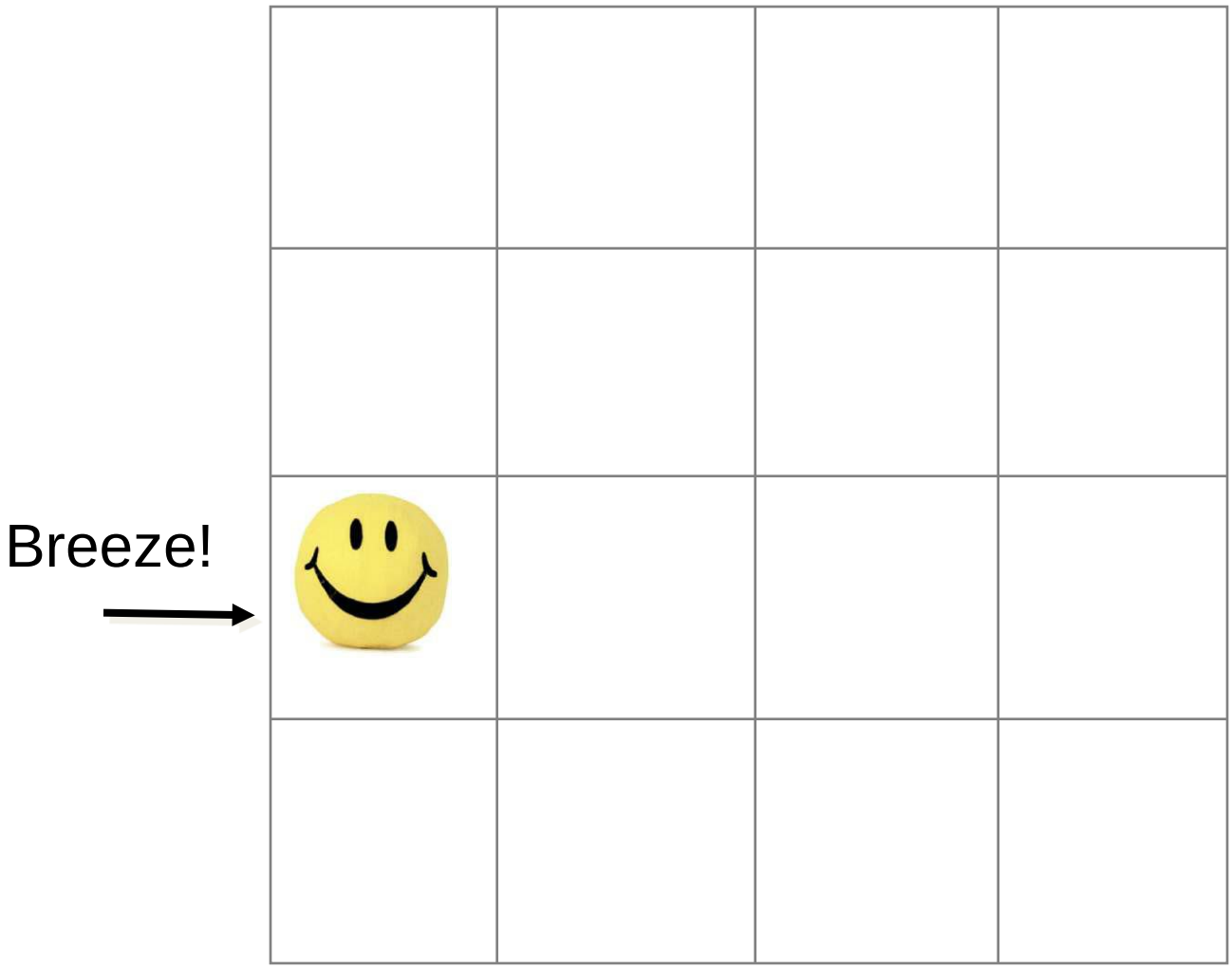

Hunt the Wumpus

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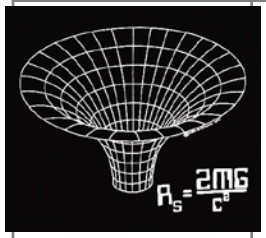

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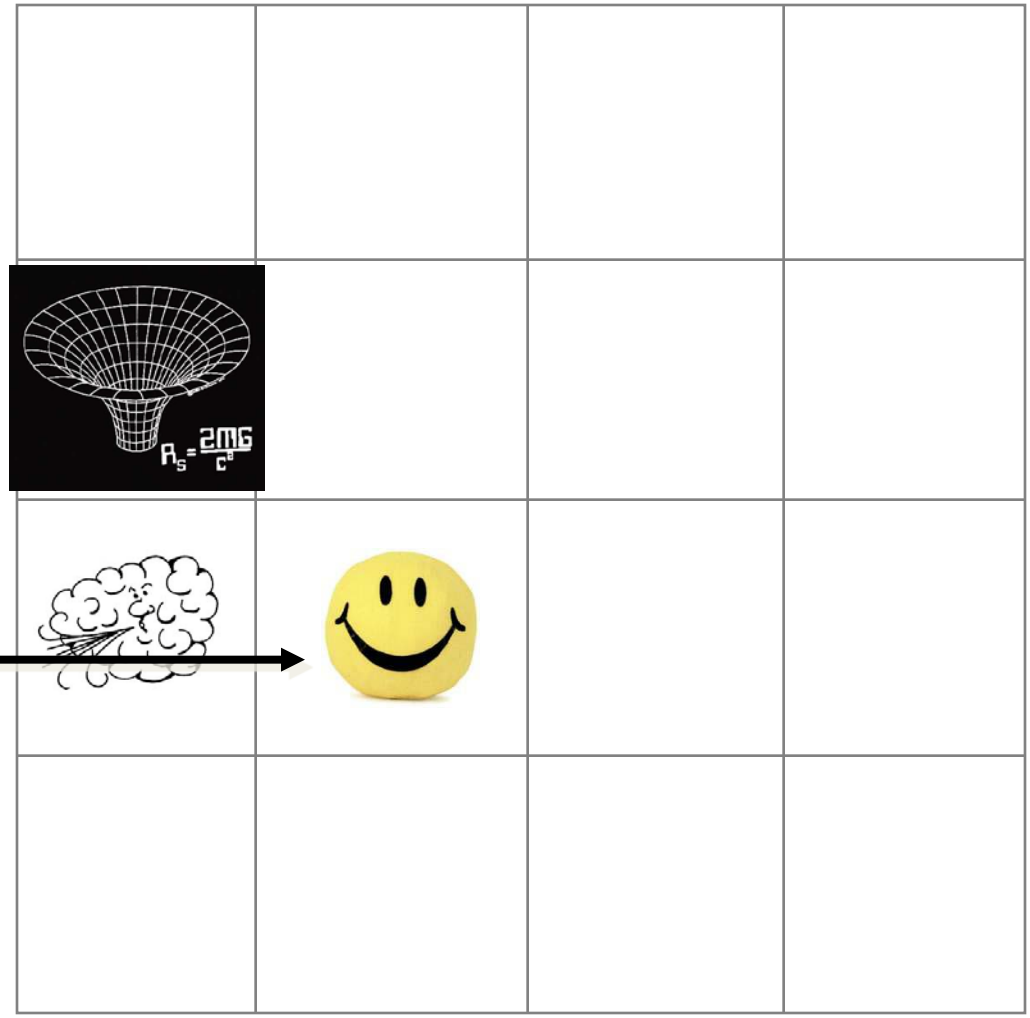

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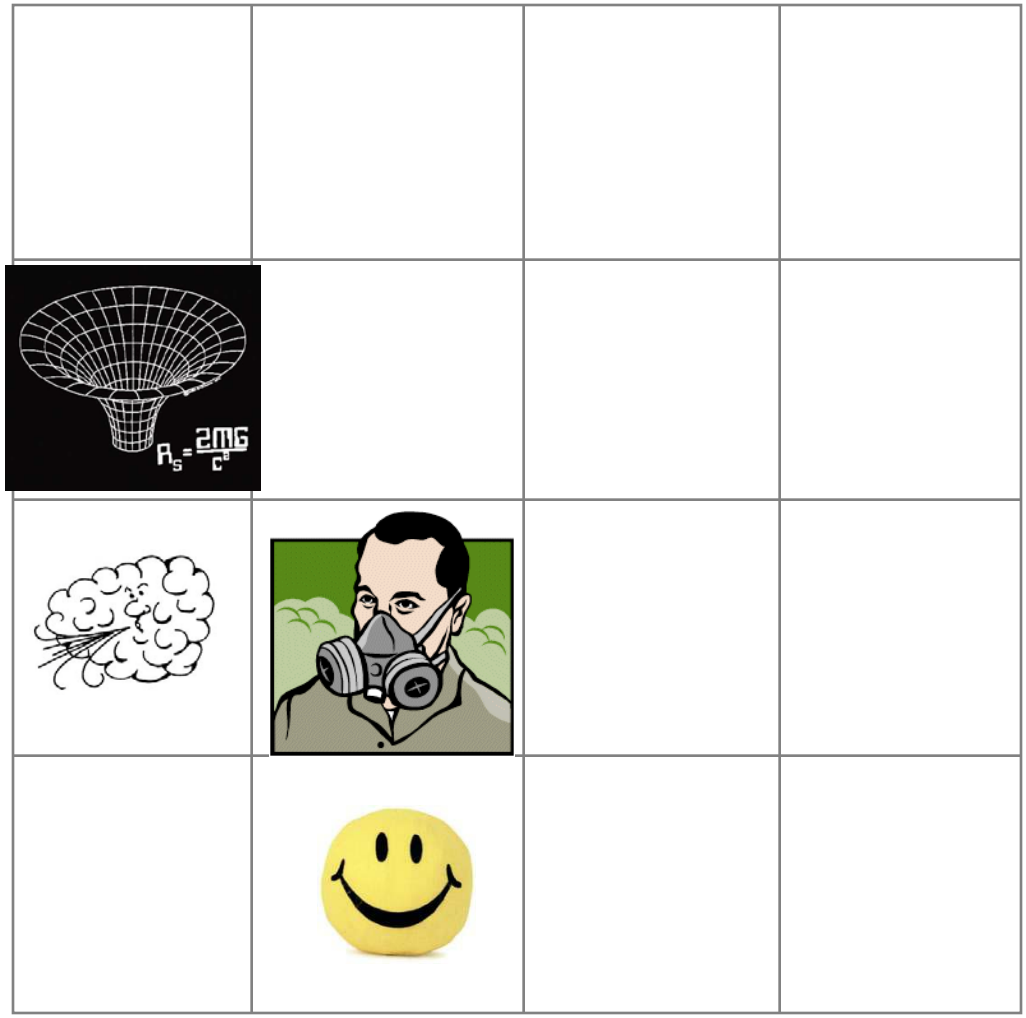

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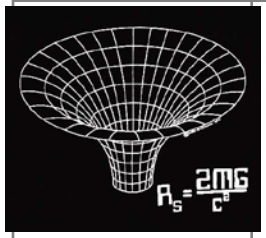

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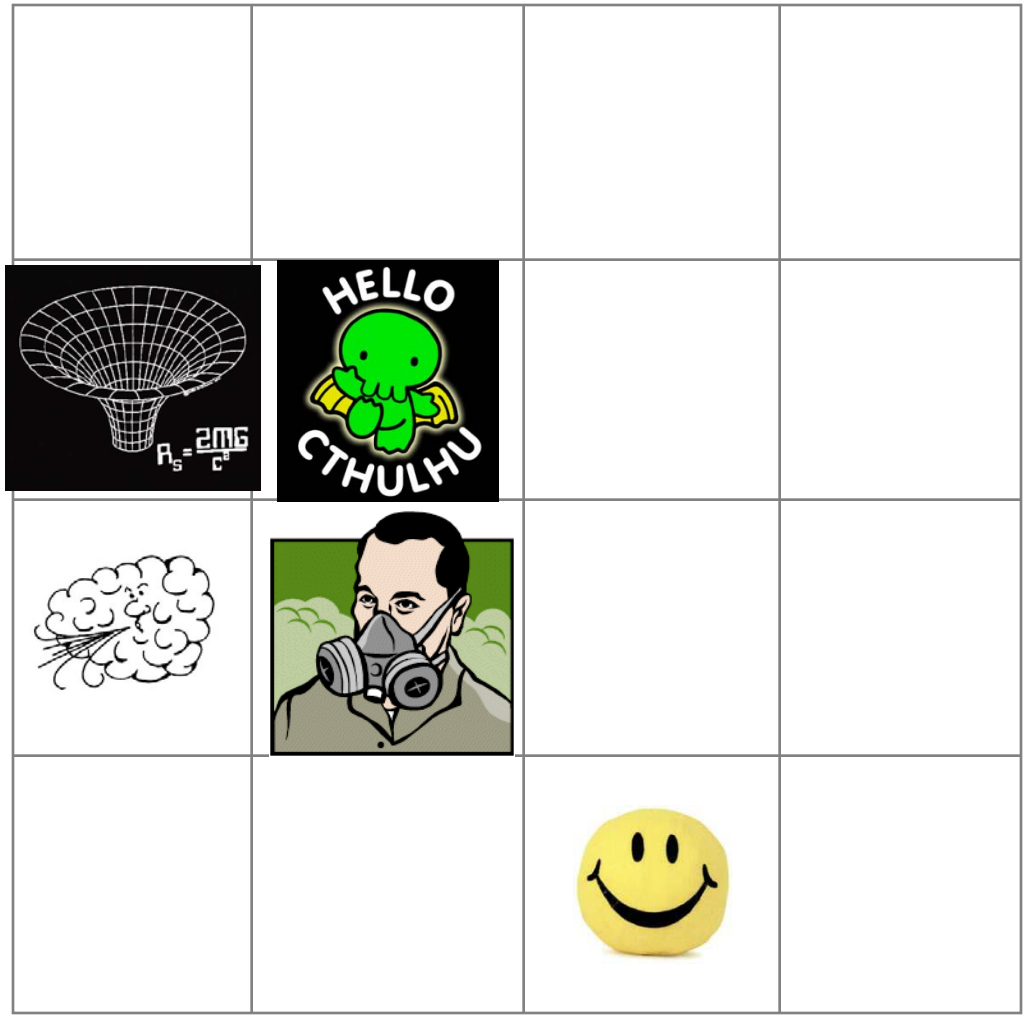
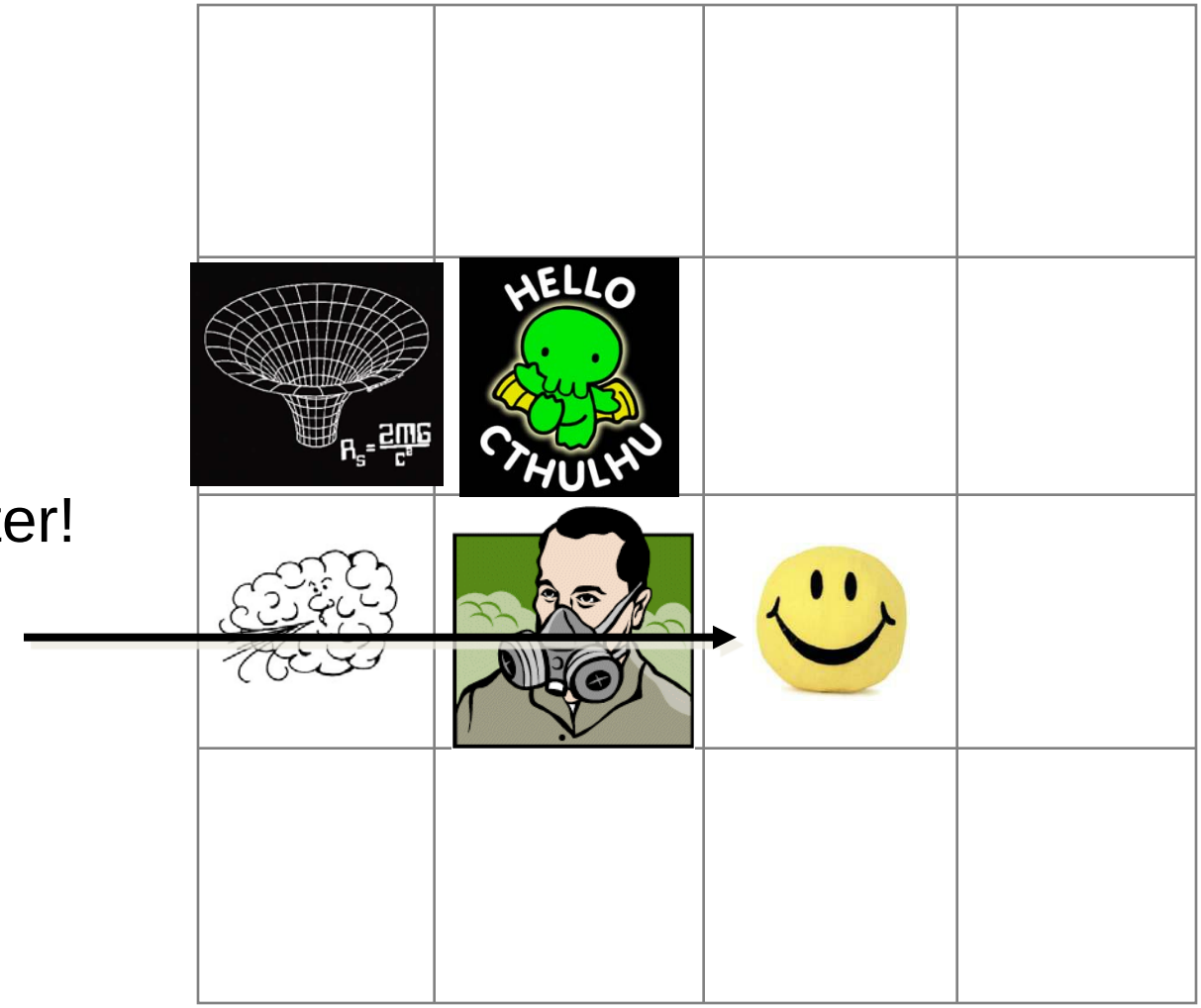


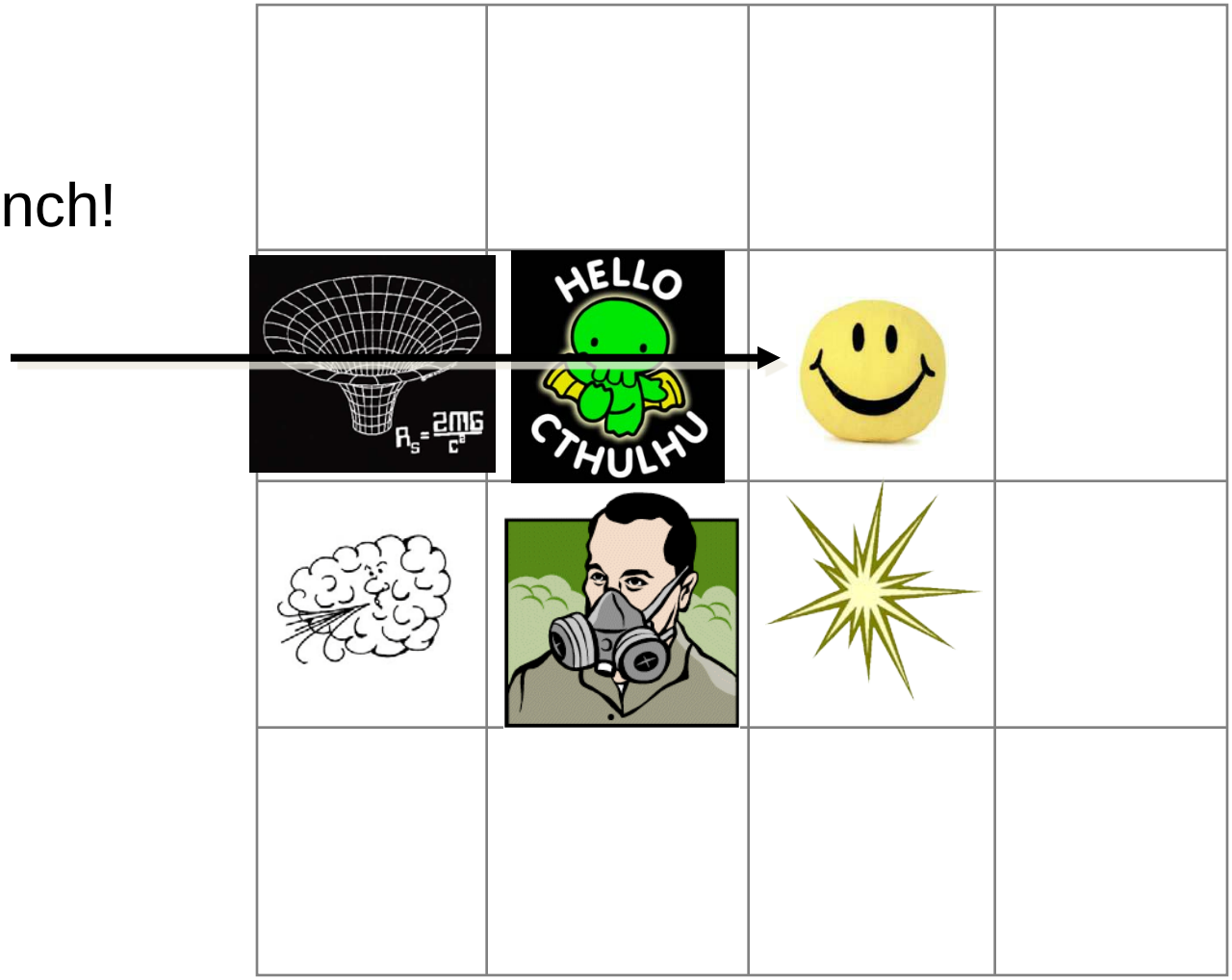
Hunt the Wumpus

Glitter!



Hunt the Wumpus

Stench!



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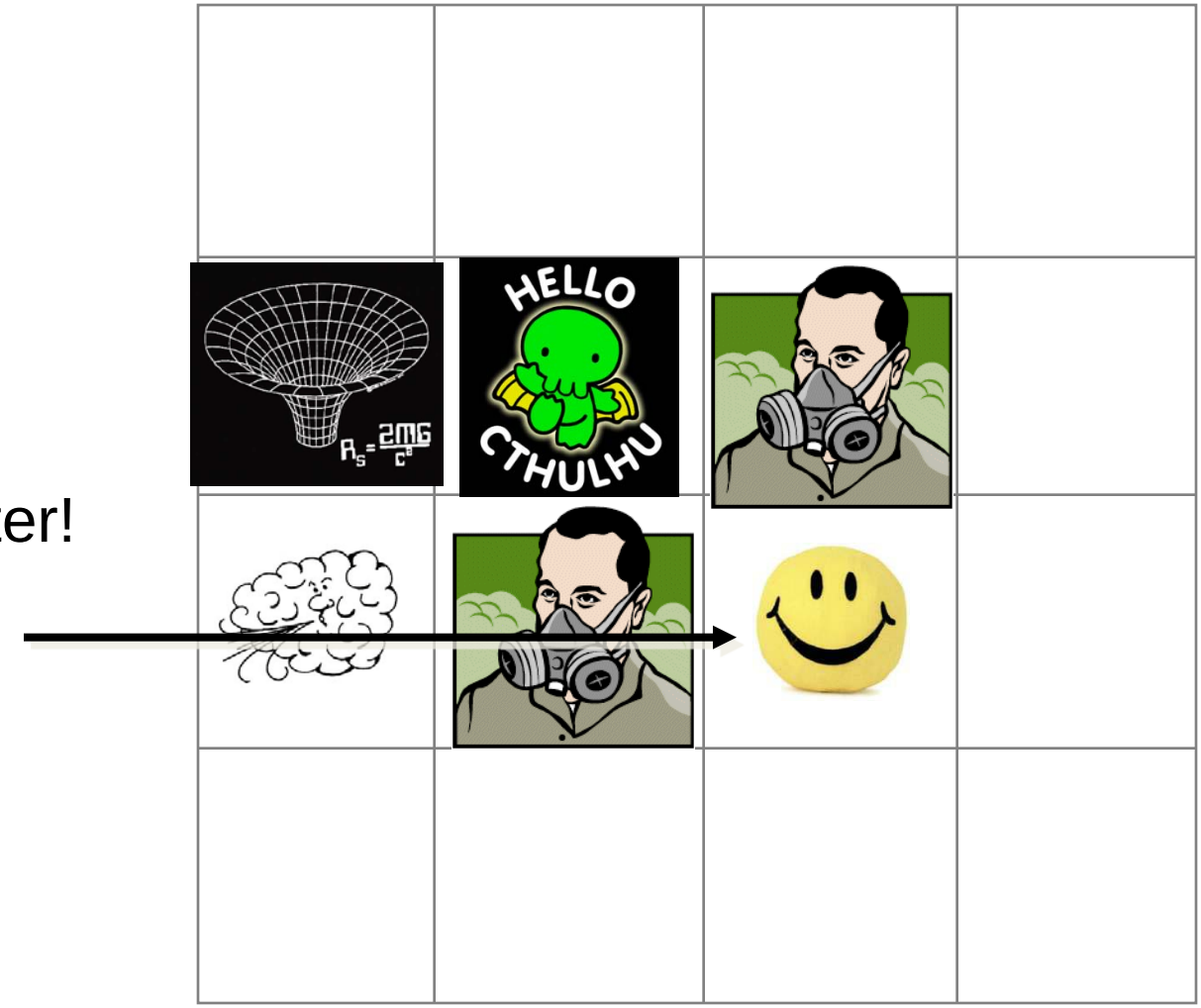

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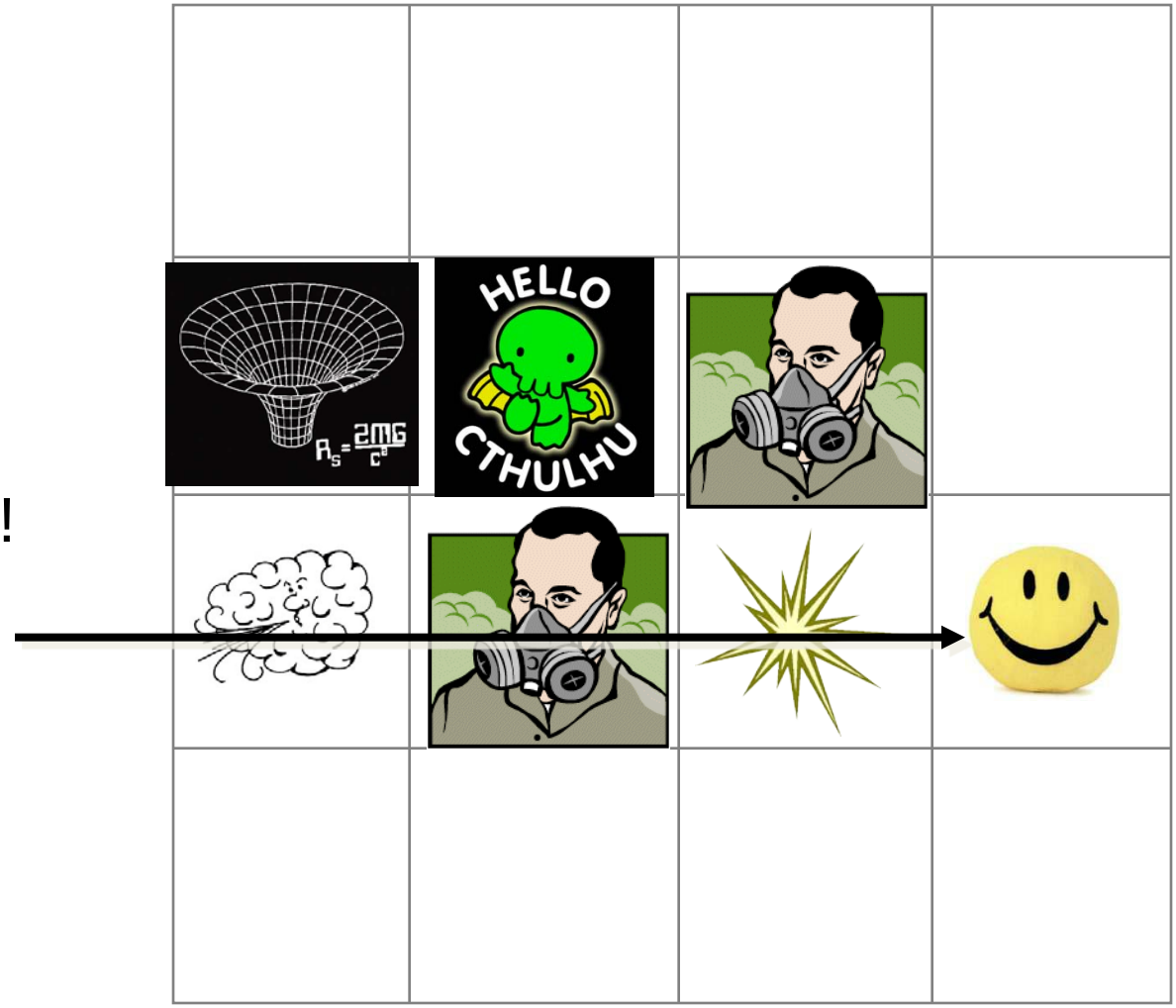
Gold!



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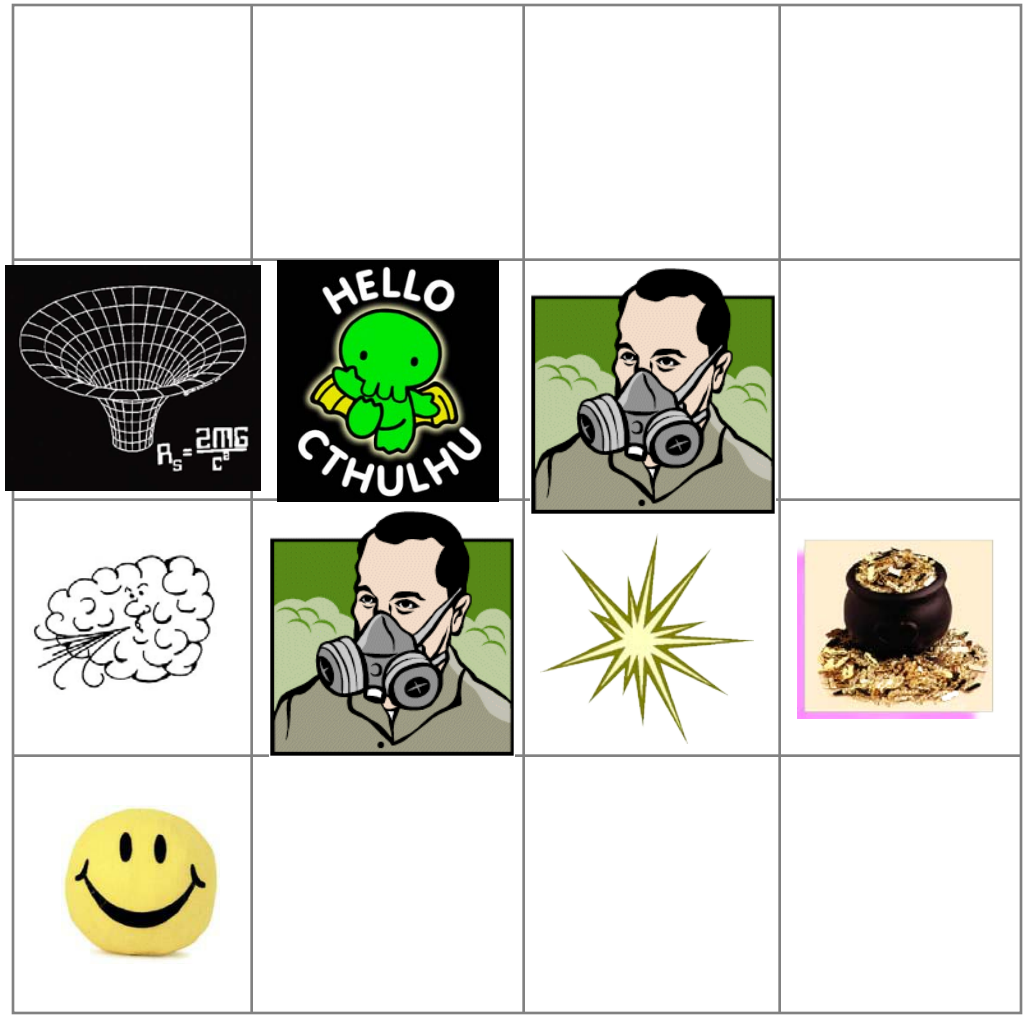
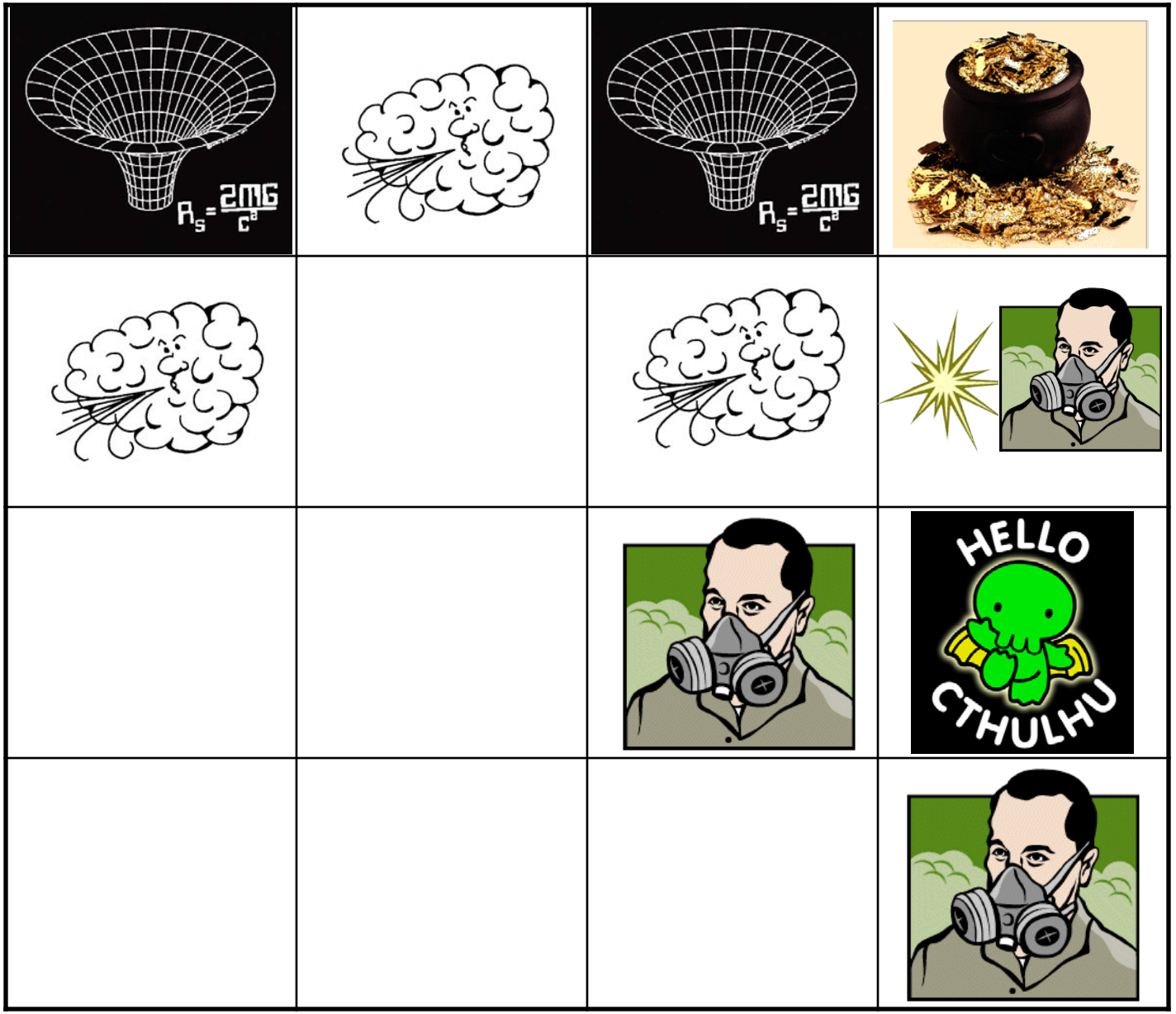




hard maze

From Cognitive Science to Robotics

- Cognitive Robotics as applying knowledge from cognitive science to robotics.
  - Cognitive psychology has described cognitive capabilities of humans
  - Cognitive science tries to build computational models that could be implemented in a robot
- But why should robots work the way humans work?
  - Maybe robots can do things better than humans!
- On the other hand, maybe there are good reasons for why humans work the way they do, and we can learn from that for robotics
  - Cognitive Science tries to understand why human cognitive capabilities are as they are

One-Trick Ponies vs General Intelligence

- Many (all?) AI and robotic systems are ‘one-trick ponies’: they do one thing really well … and that’s it.
- Human cognition is more general and adaptable.
  - Learning helps us deal with new situations
- How can we do this for robots?

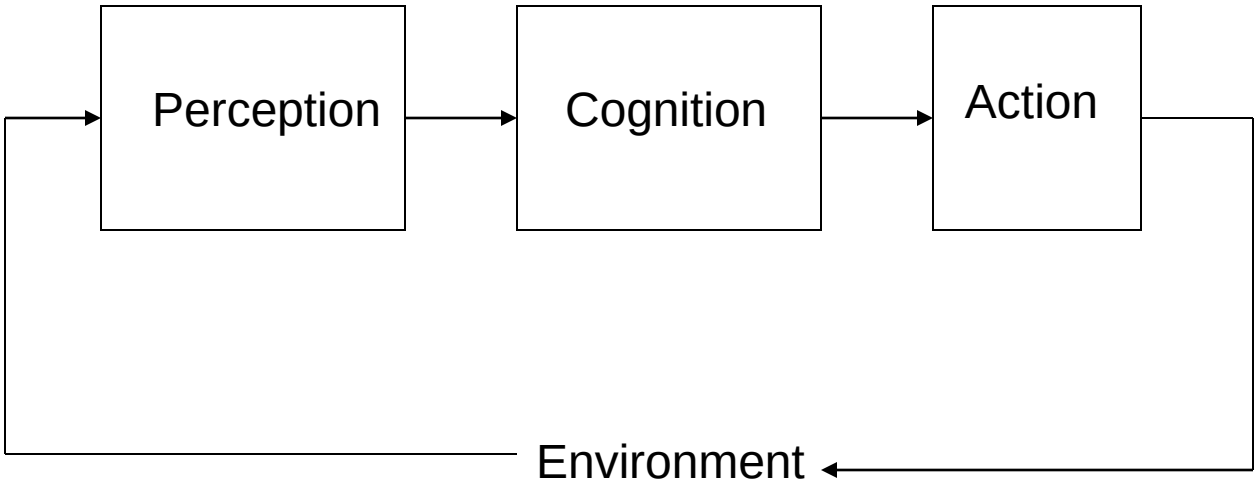
The ‘Perfect Cognizer’ vs The Adaptive Responder

- Human cognition seems to have some real drawbacks:
  - Working memory is very limited
  - Long-term memory is selective: we forget things
  - Memory is constructive: we misremember things
  - Language is ambiguous and fuzzy
  - Reasoning is often flawed
  - Etc
- But again, are these features of bad design? Or are they the necessary side effects of a product that has to function effectively in real time in different and changing environments?
  - Maybe the ‘perfect’ cognizer isn’t so perfect after all!

How Cognitive Science can Contribute Example: Vision

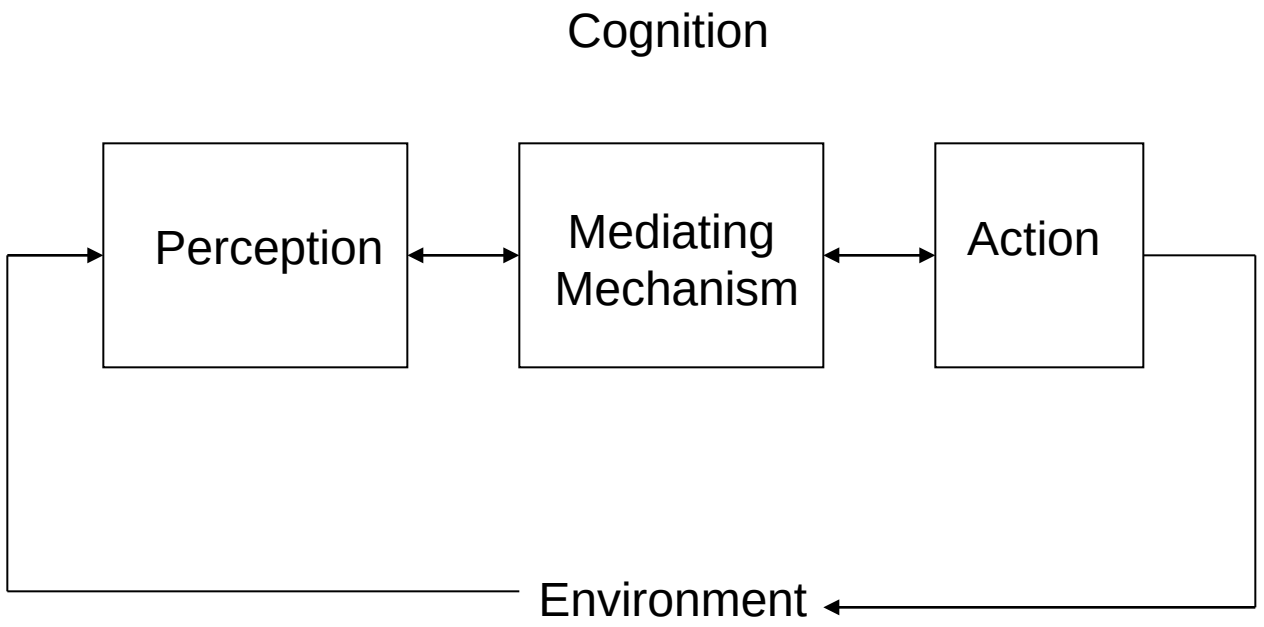
- Typical robotics/machine vision approach:
  - Bottom-Up processing of static snapshots
    - From raw data to color segmentation to edge detection to object recognition to 3D map
  - Hence:
    - More snapshots often means more work
    - Perception is ‘mere’ input to subsequent processing (‘cognition’)
- Cognitive Science Findings:
  - Plenty of Top-Down effects
    - Perception is Constructive
    - Perception is Selective
  - Indeed:
    - More input helps perception
    - Perception is integrated with other cognitive processes

Traditional Cognitive Architecture for AI or Robotics: Sense, Plan, Act



Cognitive Off-Loading: Embodied and Situated Cognition

- Embodied and Situated Cognition: Solutions are found, and cognition takes place, through interaction with environment



Advantages to Situated Approaches

- Less demand on on-board computations
- Visual feedback is good for dealing with error, changes, interruptions
- Lower-level perception-action primitives have potential to be useful to other domains. Hence, potential for domain-transfer of cognitive abilities. Or, at the very least, it allows for the exploration of new domains.

From Robotics to Cognitive Science

- Cognitive Robotics can be used to drive the science of cognition
  - Cognitive robotics as a platform to test theories about human cognition.
  - Cognitive Science as the science of all forms and kinds of cognition and cognitive agents, whether these be human, animal, alien, robot, or otherwise. Thus:
    - Robotic systems are cognitive systems, and are interesting to study in and of themselves

Cognitive Robotics as Experimental Cognitive Science

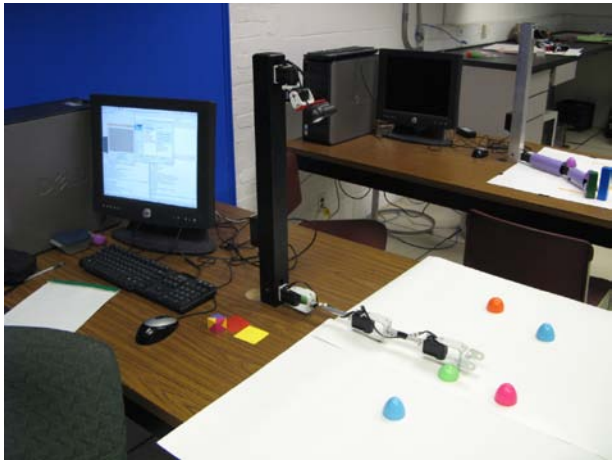
- Cognitive Robotics as the use of robotics to explore cognitive systems or architectures, to develop new concepts and frameworks of cognition, and to formulate and test cognitive hypothesis.

Cognitive Robotics @ RPI

- Typical robotics courses are about pixels and joint angles: fine for low-level image processing or solving multiple-degree-of-freedom motor control problems, but for Cognitive Robotics, I want to be able to tell the robot to “Pick up the red block” without having to worry about how it recognizes objects or move its joints to perform the required task.
- Thus, just like Programming I doesn’t start with machine code, and arithmetic doesn’t start with axiomatic number theory, I want a high-level robotic programming language, that hides low-level routines.
  - ROS (Robotic Operating System) comes with many supporting libraries.

Sage 2202: Cognitive Robotics Lab

Opened Summer 2010



Hand-Eye system

Create

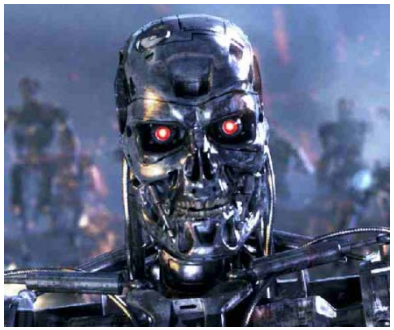
Chiara

Wanted!! Anyone interested in robots: engineers, computer scientists, cognitive scientists, social scientists, artists, etc. Let's talk!

Real Robots or Simulation?

- Real robots are more cool!
- Real robots can be a pain to get working
- Dealing with real world issues can be a feature
  - how to make robot robust and adaptive to changing circumstances and other physical ‘noise’
- Can do plenty of research into cognitive abilities of robots in simulation already

Robo-Ethics



- How can we make sure robots are used responsibly?
- Can we instill a sense of ethics into robots?
  - Hardcode something like Asimov's 3 Laws?
    - Asimov's stories show exactly the kinds of issues you'd run into with such 'crisp' rules
  - Teach robots how to behave? ("Bad robot!")