CS 440
Introduction to Artificial Intelligence

Lecture 1:

The Foundations of AI

and Intelligent Agents

21 January 2020

AI Applications

Deep Blue: First computer program to defeat human chess champion (Garry Kasperov)

IBM Watson: Trivia robot beats human contestants on trivia show Jeopardy

Self Driving Cars (e.g. Google car): May off a safer alternative to human driver

DARPA Grand Challenge: Autonomous vehicles must complete a challenging off-road course

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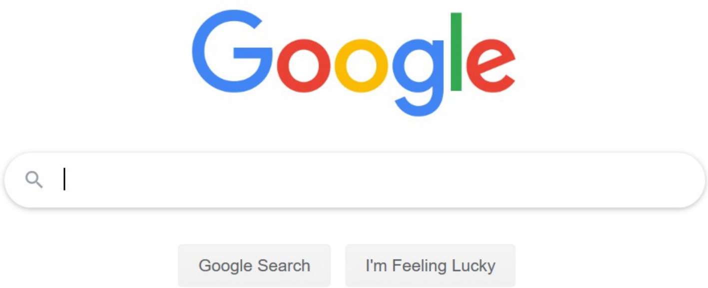
AI Applications

$$\int f(x)\,dx,$$

Integral Solver: Use order set of rules to reduce integral to



Search Engines: Map an arbitrary query to an ordered list of webpages

DOTA 2: AI program developed by OpenAI beat human world champions

SKICAT: Automatically classifies data from space telescopes and identifies interesting objects. 94% accuracy rate, significantly better than humans.

What is Artificial Intelligence?

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What is AI?

Humanly vs. Rationally

Thinking vs. Acting

	Humanly	Rationally
Thinking	“The automation of activities that we associate with human thinking, activities such as decision-making, problem solving, learning” (Bellman, 1978)	“The study of mental faculties through the use of computational models.” (Winston, 1992)
Acting	“The art of creating machines that perform functions that require intelligence when performed by people” (Kurzweil, 1990)	“AI is concerned with rational action... and studies the design of rational agents. A rational agent acts so as to achieve the best expected outcome” (S.R. & P.N., 1995)

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vs.		
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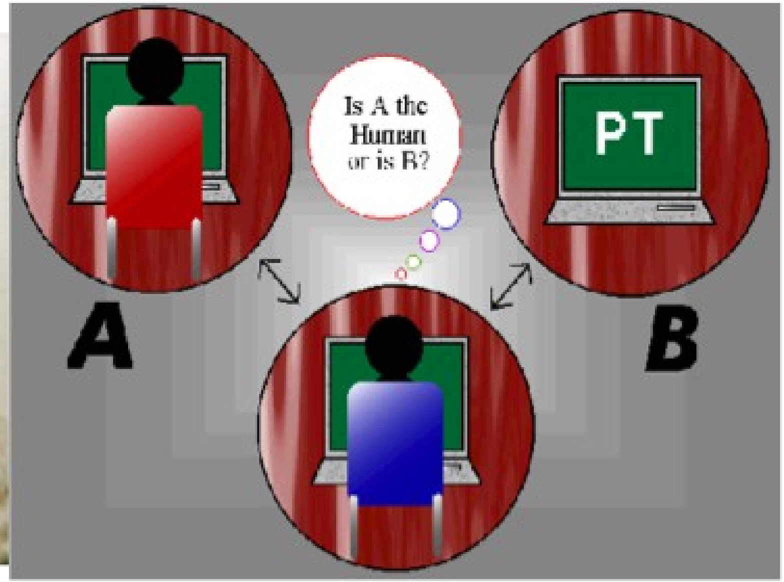
Acting Humanly

Alan Turing
(1912-1954)



Turing Test (1950)

Capabilities that the computer would need to possess:

- Natural language processing
- Knowledge representation
- Automated reasoning
- Machine learning

The total Turing test requires also computer vision and robotics

The quest for "artificial flight" succeeded when the Wright brothers and others stopped imitating birds and learned about aerodynamics.

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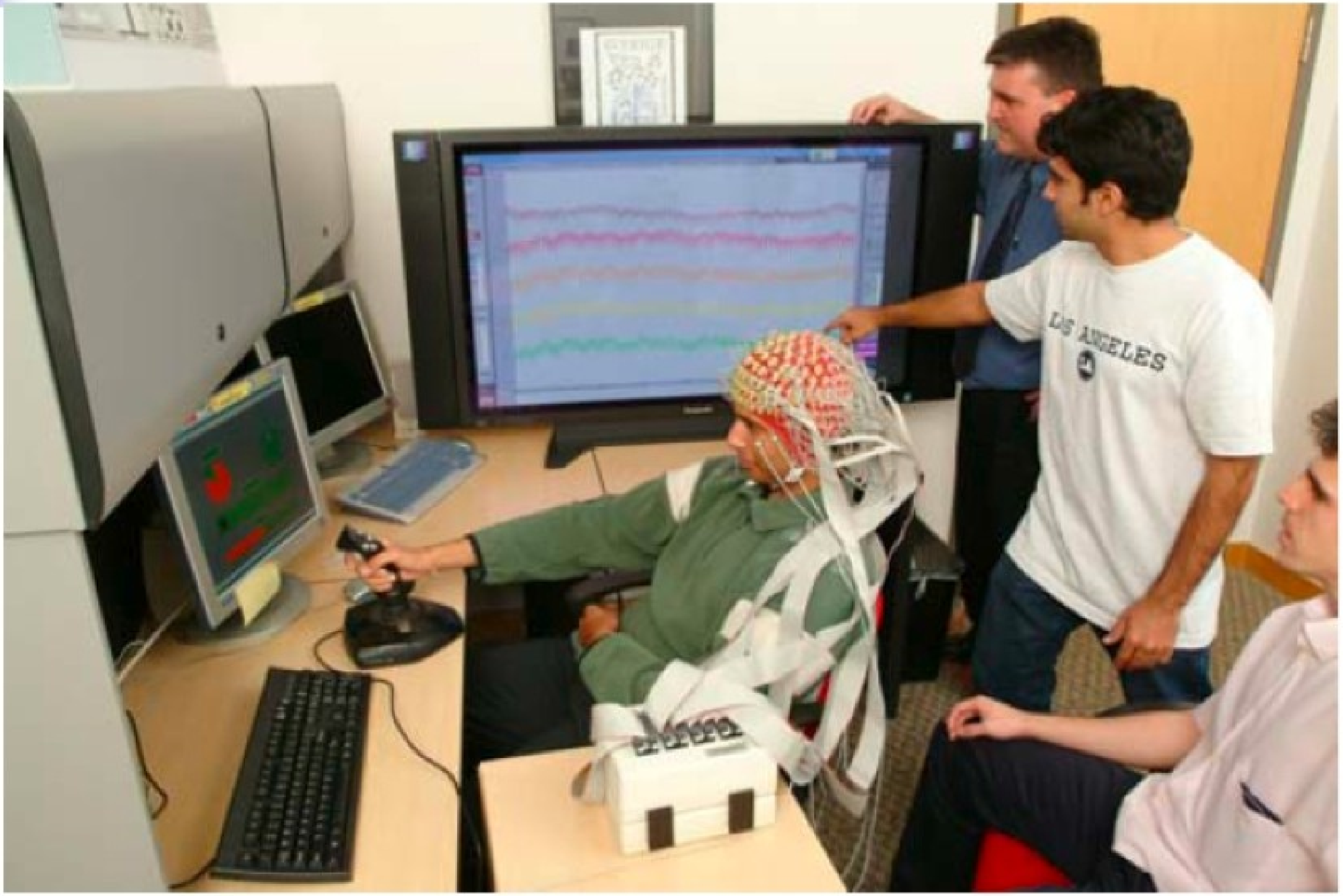
Thinking Humanly



But this if the focus of…. Cognitive science:
Requires experimental investigation of actual humans or animals

What is AI?

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Thinking Rationally

"Socrates is a man; all men are mortal;
therefore, Socrates is mortal."

Aristotle
(384-322 BC)

Logic-based AI

Logic provides:

- A syntax for describing the world and relations among objects
- A way to achieve logical/correct inferences

Create intelligent systems that
reason using the syntax and the laws of logic

By 1965 there were programs that could in principle, solve any solvable problem described in logical notation.

But…

1. How to represent knowledge in logical notation when we are less than 100% certain?
2. Computational explosion:

A few hundred of facts exhaust the computational resources of any computer when it attempts logical inference without some sort of guidance

What is AI?

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Humanly vs. Rationally

Thinking vs. Acting

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Acting Rationally

Stuart
Russell

Logical inference is part of intelligence. It does not cover everything:

- e.g., might be no provably correct thing to do, but still something must be done
- e.g., reflex actions can be more successful than slower, carefully deliberated ones

What is a rational action?

One that achieves the best outcome

(or in the case of uncertainty… the best expected outcome)

Peter
Norvig

It is this objective that requires:

- Natural language processing
- Knowledge representation
- Automated reasoning
- Machine Learning
- Computer Vision
- Robotics

"Human behavior is well adapted for one specific environment and is the product, in part, of a complicated and largely unknown evolutionary process that is still far from producing perfection."

YAHOO! RESEARCH
NSF
AI Music Composition & Performance
AI Paintings
Robot Soccer
Humanoid Robot
How Can AI Systems Learn From Experience?
Social Simulation Game
How Can AI Systems Have Common Sense?
Autonomous Vehicle
Robot Tour Guide
Characters for Virtual Worlds
Smart Environmental Controls
Intelligent Tutoring System
Vehicle Navigati
Smart Desk with Gesture Recognition
How Can AI Systems Understand By Seeing, Hearing, Acting, & Explaining?
Autonomous Space Exploration
Personalized TV Guide
How Can AI Systems Solve Problems Creatively?
Robots for Education
Robot Vacuum Cleaner
Recommender System
Aristotle
Robotic Surgery
How Can AI Systems Cooperate Effectively With Humans?
Where & When Do We Need AI Systems?
Disease Diagnosis
AI LAB
Drug Design
Fraud Detection
Leibniz
Descartes
Whitehead
Lovelace
Russell
Turing
AI CENTER
Smart Wheelchair
Web Search
BOOKS & COFFEE
BOOKS
Handwriting & Sketch Recongnition
Spam Filtering
Machine Translation
1956
See the AI timeline and more at www.aaai.org/AILandscape
The AI Landscape

AAAI Topics

- AI and the Web
- Cognitive Modeling
- Cognitive Systems
- Computational Sustainability and AI
- Computational Discovery
- Game Theory and Economic Paradigms
- Game Playing and Interactive Entertainment
- Heuristic Search and Optimization
- Human-Computation and Crowd Sourcing
- Humans and AI
- Knowledge Representation and Reasoning
- Machine Learning Applications
- Multi-agent Systems
- Natural Language Processing (NLP) and Knowledge Representation
- NLP and Machine Learning
- NLP and Text Mining
- Novel Machine Learning Algorithms
- Planning and Scheduling
- Reasoning under Uncertainty
- Robotics
- Search and Constraint Satisfaction
- Computer Vision

Some success stories

- **SKICAT:** automatically classifies data from space telescopes and indentifying interesting objects in the sky. 94% accuracy, way better than human *(decision trees)*
- **Deep Blue:** the first computer program to defeat human champion Garry Kasparov *(minimax search + alpha-beta-pruning + optimizations)*
- **Pegasus, Jupiter, etc.:** speech recognition systems *(Hidden Markov Models)*
- **HipNav:** a robot hip-replacement surgeon *(planning algorithms)*
- **DARPA Grand/Urban Challenge:** autonomous driving *(filtering and planning algorithms)*
- **Deep Space 1:** NASA spacecraft that did an autonomous flyby an asteroid *(logic-based AI)*
- **Credit card fraud detection** and loan approval *(decision trees and neural networks)*
- **Chinook:** the world checker's champion *(game theory)*
- **Spam Assassin** and other spam detectors *(naïve Bayes learning)*
- **Soccer playing Aibo robots** *(reinforcement learning)*

Latest trend: Deep Learning

House Number Identification in Street View*

*“Multi-digit Number Recognition from Street View Imagery using Deep Convolutional Neural Networks“ by Ian J. Goodfellow, Yaroslav Bulatov, Julian Ibarz, Sacha Arnoud, Vinay Shet

Image Classification (query animal)

ImageNet classification results

1M training images, 1K categories, top-5 error

Best deep-learning models	~9%
Non-deep learning models ISI, Japan Oxford, England INRIA, France University of Amsterdam, etc.	~26%

Similar improvements in speech recognition, text understanding and automated translation

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AI Problem Definition

How do you describe an AI problem?

Environment

How do you describe an AI problem?

- Environment

Environment

- The world in which the problem takes place
- Could be a physical environment or a virtual environment

Examples

- Chess: The chess board
- Image recognition: The real objects
- Robotics: The physical world around the robot

Perception/Observation

How do you describe an AI problem?

- Environment
- Perceptions/Observations

Perceptions/Observations

- Inputs the agent receives

Examples

- Chess: The
- Image recognition: An image file
- Robotics: Sensor readings

Convention

- Let **O** be the set of all possible observations
- Let **o**ϵO refer to an individual observation

Actions

How do you describe an AI problem?

- Environment
- Perceptions/Observations
- Actions

Actions

- Operations the agent can perform

Examples

- Chess: A valid move
- Image recognition: A label for the image
- Robotics: Motor or actuator control

Convention

- Let **A** be the set of all possible actions
- Let **a**$\in$**A** refer to an individual action

Evaluation

How do you describe an AI problem?

- Environment
- Perceptions/Observations
- Actions
- Evaluation

Evaluation

- Feedback

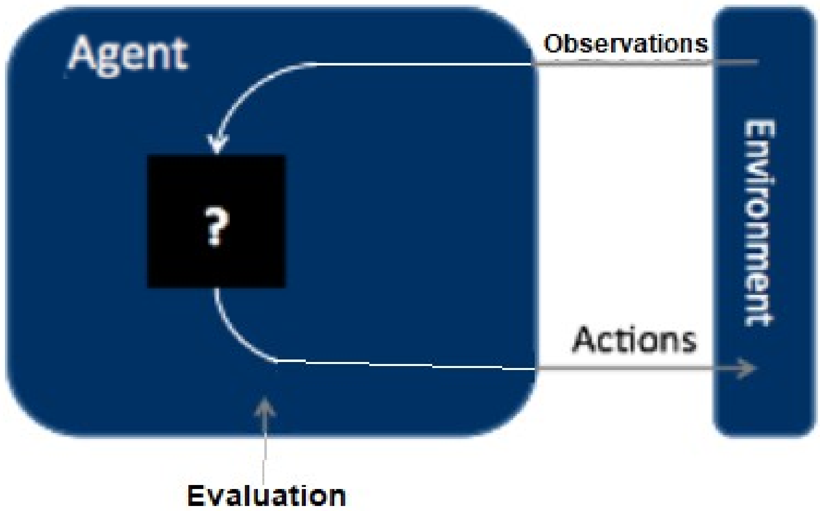
Examples

- Chess:
  - Positive evaluation if wins
  - Negative evaluation if looses
  - Neutral if draws
- Image recognition:
  - Positive evaluation if labels image correctly
- Robotics:
  - Positive evaluation if robot reaches some goal
  - Negative evaluation if robot collides with obstacle

AI Problem Definition

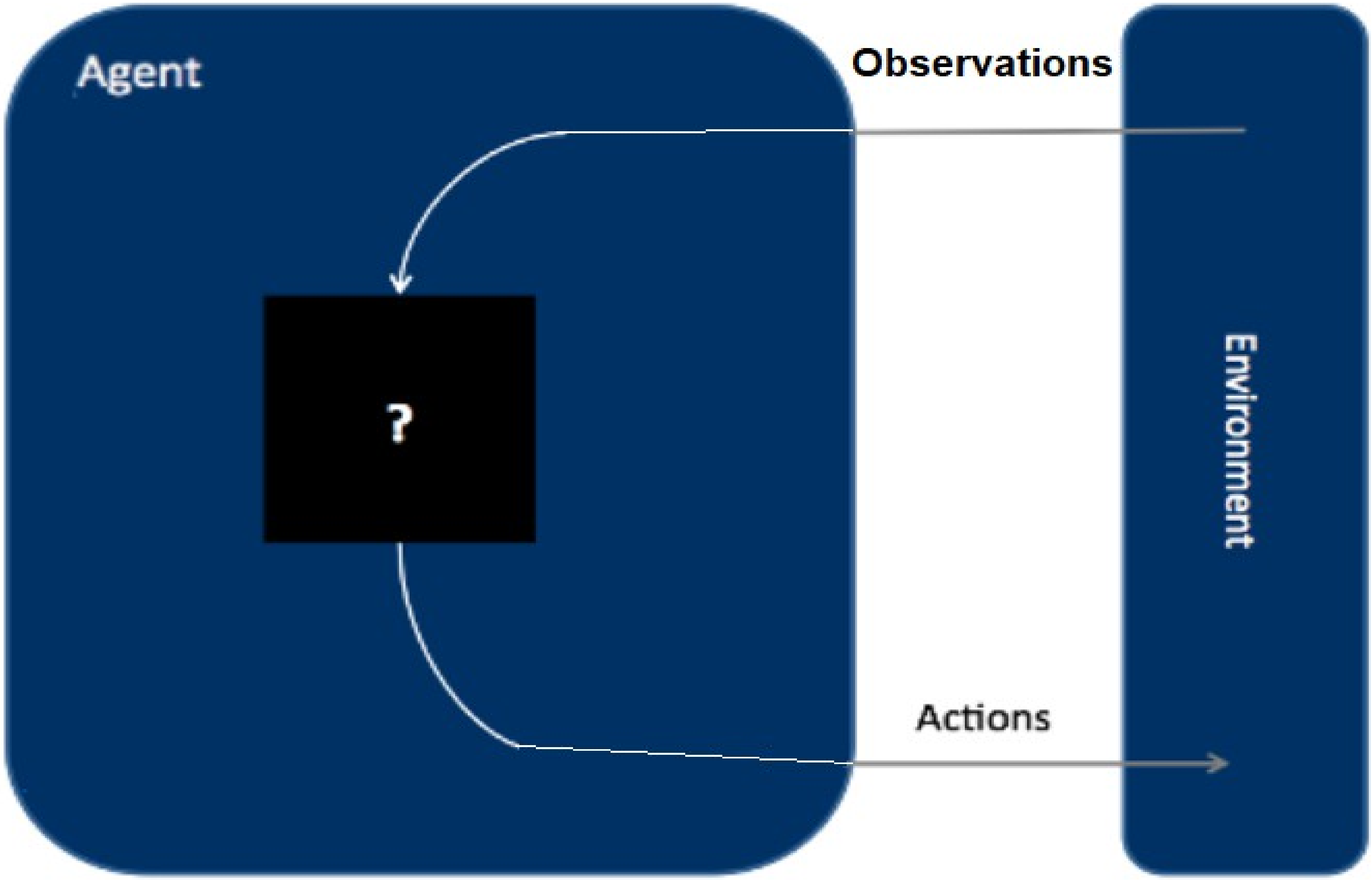
How do you describe an AI problem?

- Environment
- Perceptions/Observations
- Actions
- Evaluation

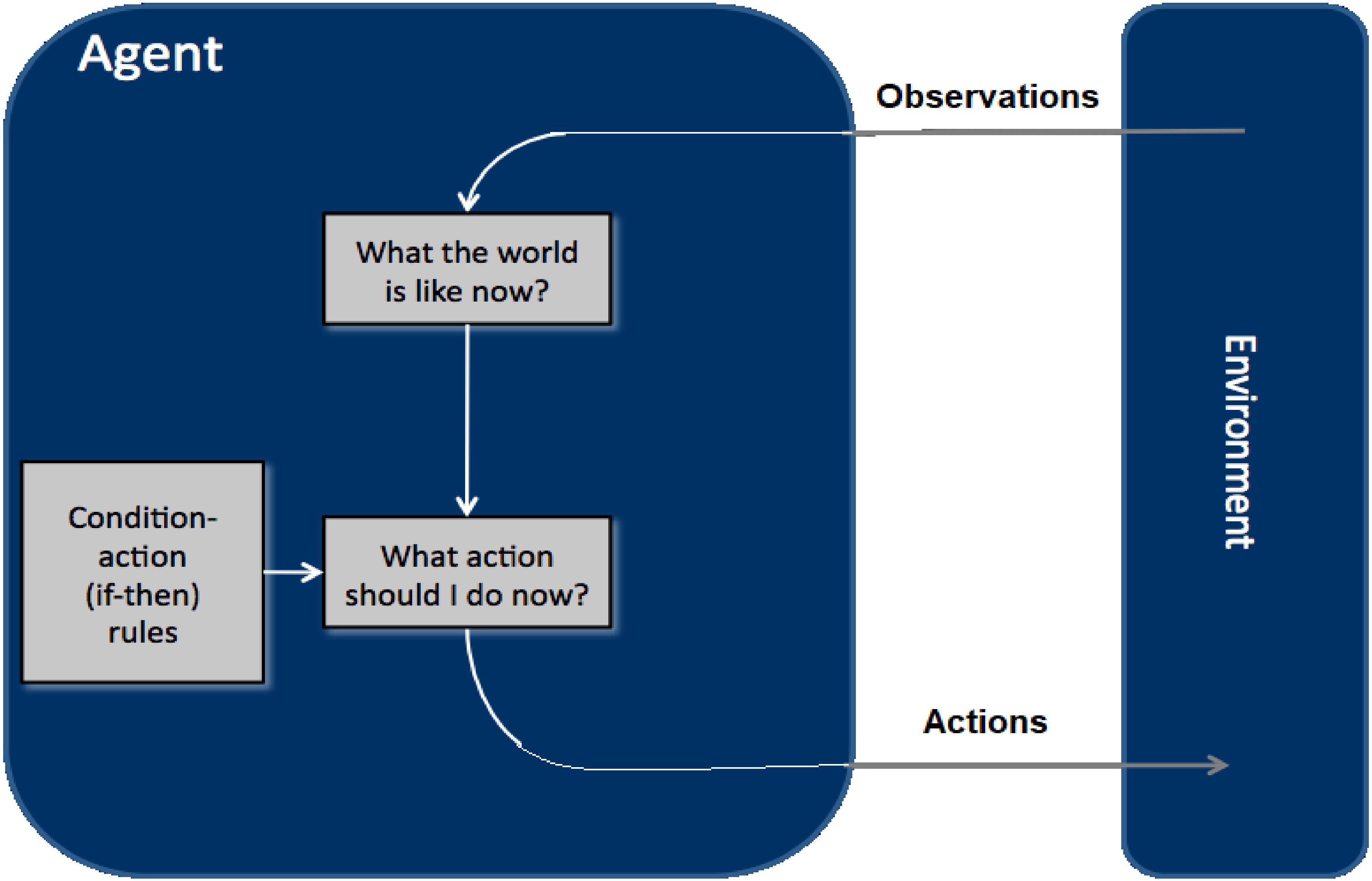


Select an action that yields best evaluation given the observations as well as any built-in knowledge the agent has about its environment.

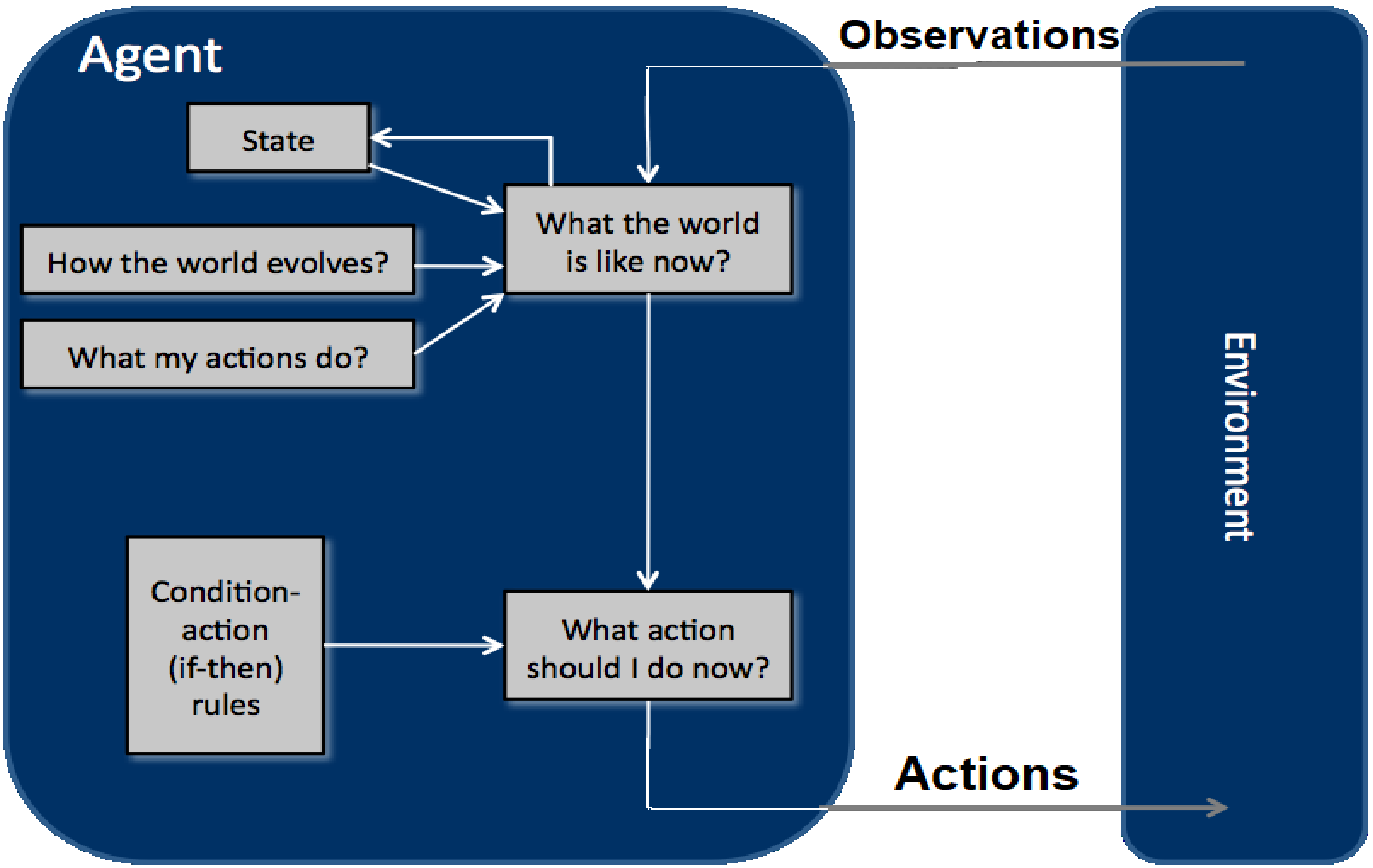
How do agents work?



Reflex Agents

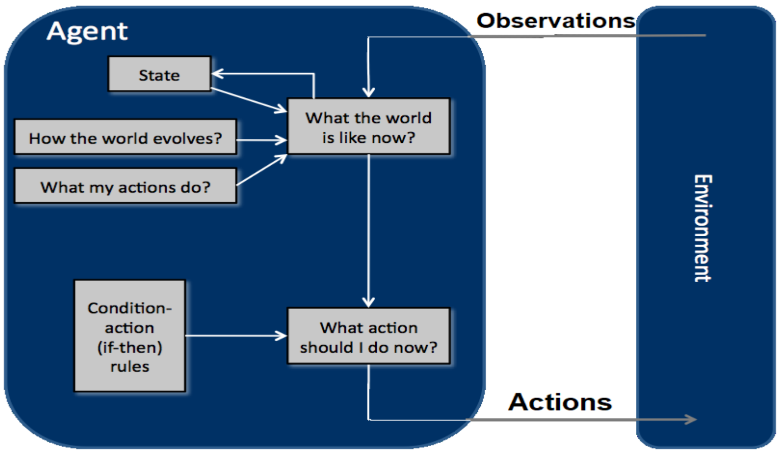


Model-based Reflex Agents



States

How should the agent represent the environment?



State:

- Data structure representing environment
- Incorporate all relevant information

Examples:

- Chess: An 8x8 array
- Image recognition: An array of RGB values
- Robotics: A geometric representation of the environment

Convention:

- Let S be the set of all states
- Let $s \in S$ denote an individual state

Challenges

- States are problem specific
- Size needs to be reasonable
-

Hint: think about if you can represent problem using common data structure such as array or graph.

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States

State:

- Incorporate all relevant information

Examples:

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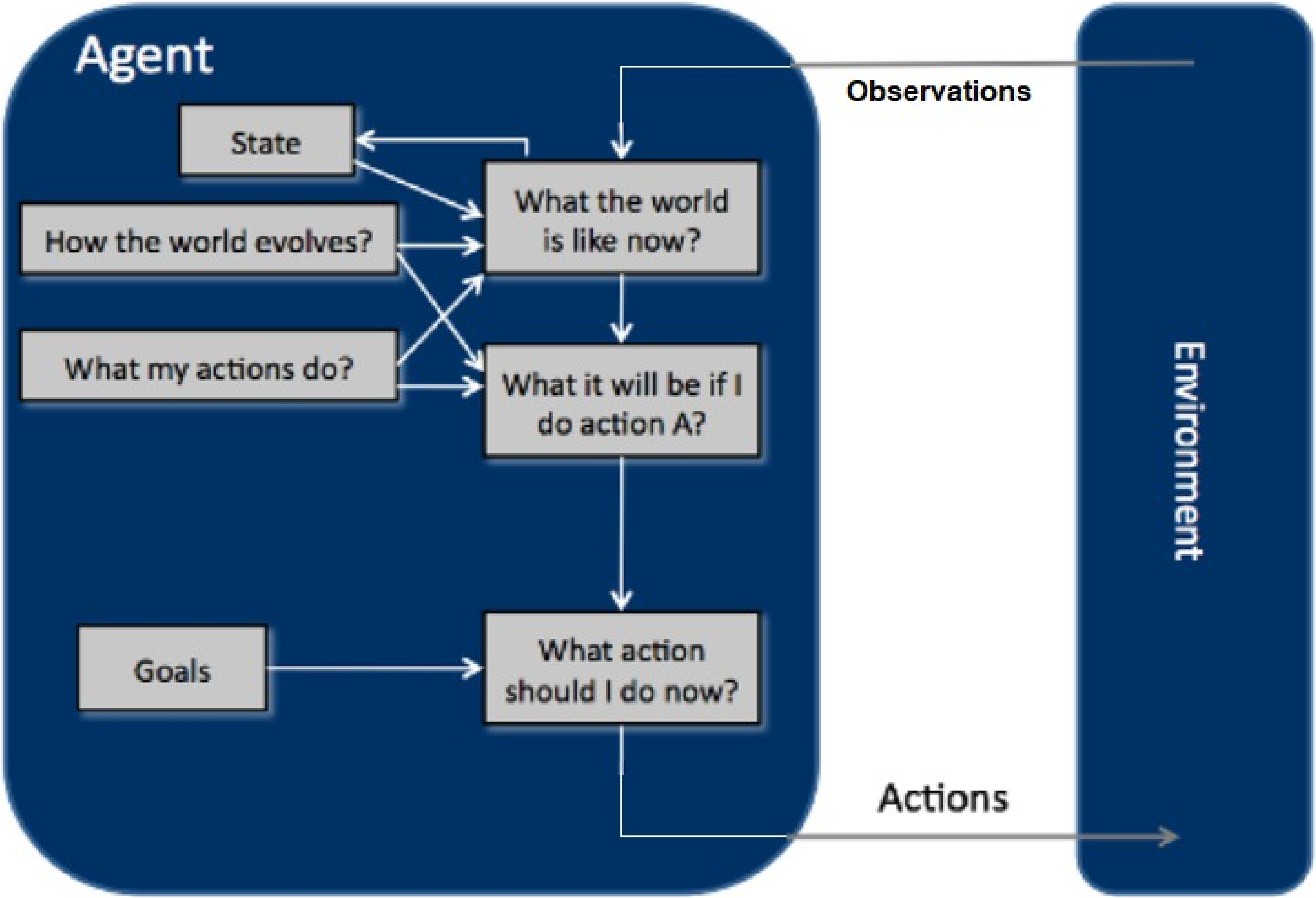
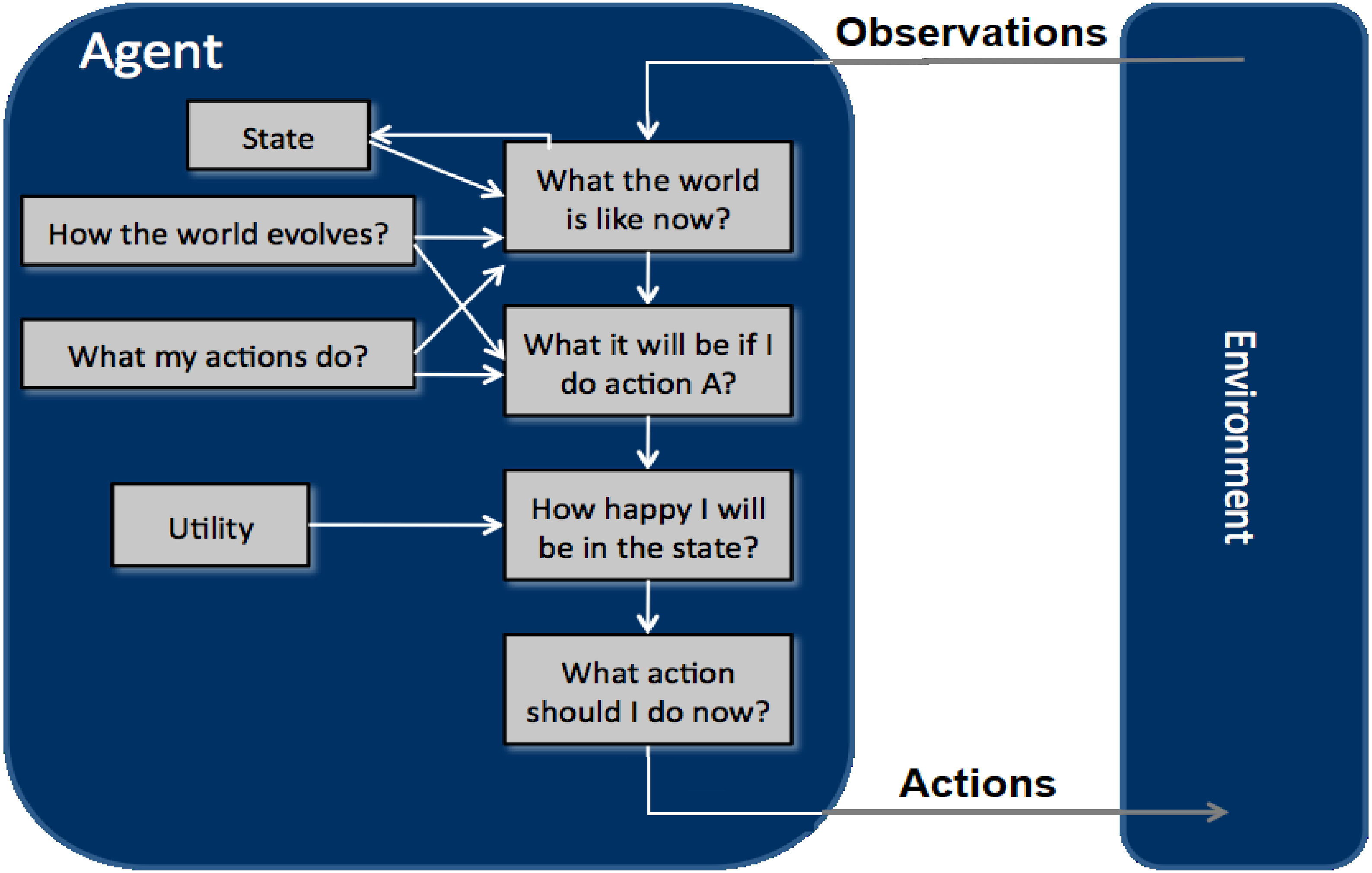
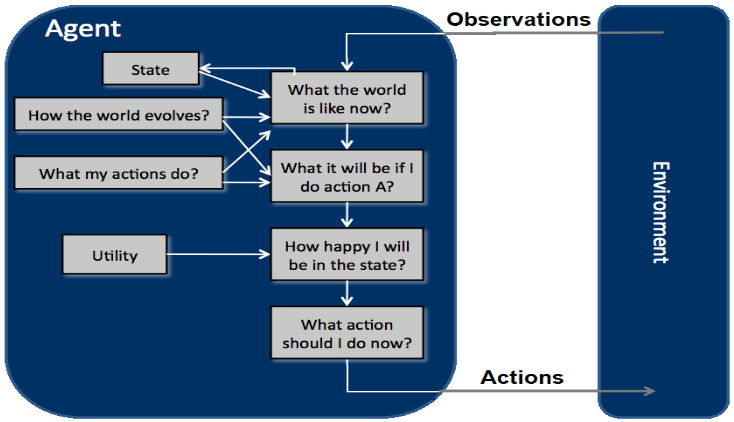
Goal-based Agents



Utility-based Agents



Utility



How should the agent reason about utility?

Utility function:

- Assign a utility value to each state

Examples:

- Chess: Value of pieces captured / lost
- Robotics: Distance to goal position

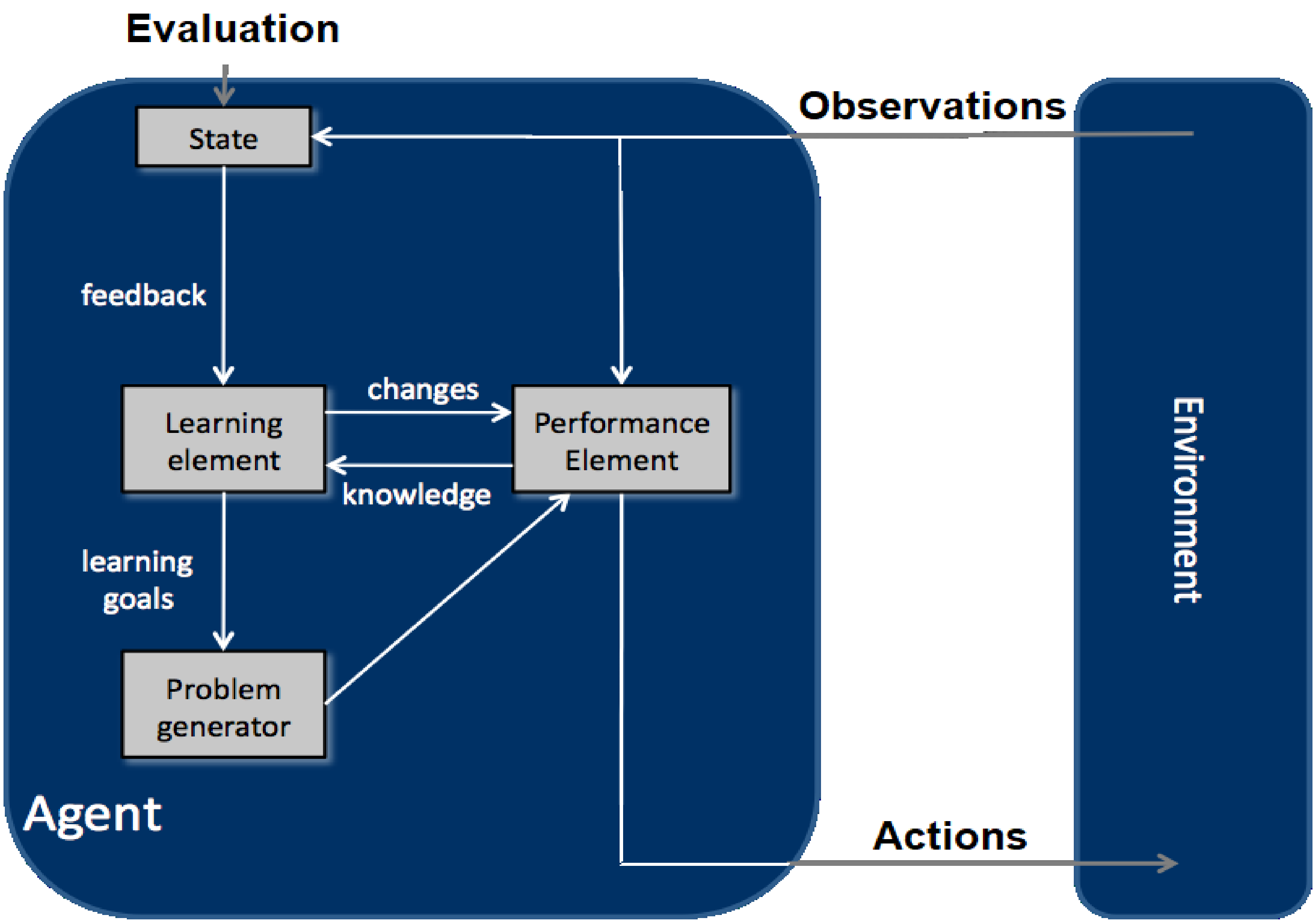
Convention:

- Let **r(s)** define the utility of state **s**

Challenges

- Utility functions are problem specific
- A lot of thought must be given to come up with good metric
  - Trial and error

Learning Agents



Environments and their Properties

<u>Fully observable vs. partially observable:</u>

- If the agent has always access to the complete state of the environment, then the environment is fully observable
- Partial observability due to: noisy, inaccurate sensors or sensor limitations

<u>Deterministic vs. stochastic:</u>

- If the next state of the world is completely determined by the current state and the agent's action, then the environment is deterministic.
- If the environment is deterministic except from the actions of other agents, then it is called strategic.

<u>Episodic vs. sequential:</u>

- In an episodic environment the agent's experience does not depend on the actions taken in previous episodes.
- In sequential environments, the current decision could affect all future decisions.

Environments and their Properties

Static vs. dynamic:

- If the environment changes while the agent is not acting, then the environment is dynamic.

Discrete vs. continuous:

- Continuous values can appear in:
  - The state of the environment, time, the percepts or actions of the agent.

Single agent vs. multiagent:

- When are the other entities in the world considered agents?
  - Competitive environments:
    - When they maximize an performance measure that depends on the agent's actions
  - Cooperative environments:
    - When they communicate or follow common rules so as to satisfy a common performance measure

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Structure of the Book

Part 1

- Decision-Making in Deterministic Environments
  - Uninformed search, informed search and heuristics, randomized and local search (genetic algorithms), adversarial search, constraint satisfaction, logic-based inference, task and path planning

Part 2

- Decision-Making in Stochastic Environments
  - Bayesian networks, Hidden Markov Models, Kalman and Particle filters, Decision and Utility theory, Markov Decision Processes

Part 3

- Learning in Unknown Environments
  - Supervised learning: Decision trees, Support Vector Machines, Neural Networks
  - Unsupervised learning: Introduction to Reinforcement Learning

Discussion

- What agent types are best suited for which environments/properties?
- For which environments/properties are some of the agent types equivalent?