Artificial Intelligence ENCS 434

Introduction

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Syllabus

Course Information	
Course Title	Artificial Intelligence
Course Number	ENCS 434
Text Book	• Artificial Intelligence: A modern approach 3rd edition • Artificial Intelligence: A Guide to Intelligent Systems 3rd edition
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Grading Scheme		
Assessment Type	Date	Weight
Midterm Exam	TBA	25%
Final Exam	TBA	40%
Assignments	TBA	35%
Quizzes	TBA	5%

Syllabus

Topics	Time (Lectures)
• Introduction - Intelligent Agents	2
• Problem Solving by Search	4
• Heuristic (Informed) Search	4
• Constraint Satisfaction	3
• Games	3
• Knowledge-Based Agents - Propositional and First-Order Logic	3
• Inference in First-Order Logic, Logic Programming and Prolog	3
• Planning	4
• Uncertainty and Probabilistic Reasoning	5
• Fuzzy Logic	4
• Machine Learning - Basic Concepts, Decision Trees, Neural Networks	7
• Introduction to Natural Language Processing	2

Course Learning Outcomes

- Upon completion of this course, you will have the ability to:
  - Understand the meaning of AI, its alternative approaches.
  - Know the techniques and technologies that currently exist and are "evolving" in the field of AI.
  - Know a variety of ways to represent and retrieve knowledge; Logic, semantic networks, frames, production rules.
  - Expand your knowledge about blind and heuristic search algorithms.
  - Know the fundamentals of AI programming languages; Prolog.
  - Know machine learning techniques and apply them in an AI programming language.
  - Understand the basic methods in planning and reasoning using both logic and uncertain inference.

What is Artificial Intelligence ?

- Intelligence = Knowledge + ability to perceive, feel, understand, process, communicate, judge, and learn.

- **What is Artificial Intelligence?**
  - There is no official agreed upon definition of Artificial Intelligence.
  - In practice, it is an “umbrella term”
  - It is multidisciplinary subject
  - Technologies enter and exit the AI “umbrella” regularly.

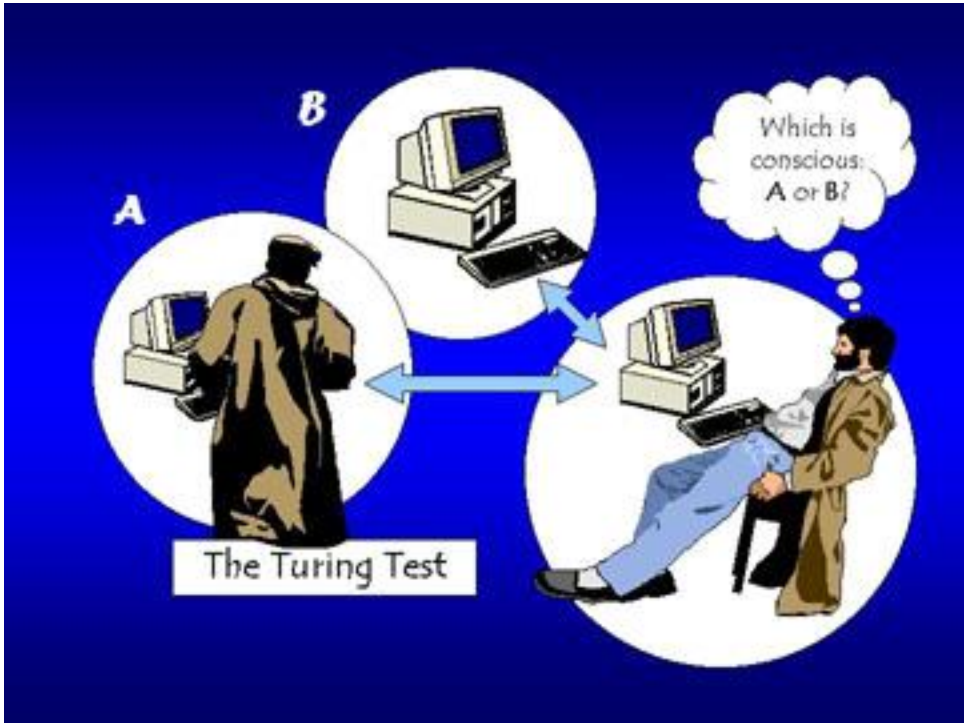
- **General Goal:** replicate human intelligence

What is Artificial Intelligence ?

- Winston: "AI is the study of ideas which enable computers to do things which make people seem intelligent."
- Steven Tanimoto, "Computational techniques for performing tasks that apparently require intelligence when performed by humans."
- David Parnas, "Artificial intelligence is to artificial flowers as natural intelligence is to natural flowers."
- Luger: The branch of computer science that is concerned with automation of intelligent behavior.
- Rich: "AI is the study of how to make computers do things which, at the moment, people do better."
- Fahlman: AI is the study of intelligence using the ideas and methods of computation."
- Found on the Web: AI is the reproduction of the methods or results of human reasoning or intuition.
- We can define it too: AI is a field of computer science that simulates human performance to make a computer reasons in a manner similar to humans.

What is Artificial Intelligence?

Turing Test



The computer passes the "test of intelligence" if a human, after posing some written questions, cannot tell whether the responses were from a person or not.

What is Artificial Intelligence?

- To give an answer, the computer would need to possess some capabilities:
  - Natural language processing: To communicate successfully.
  - Knowledge representation: To store what it knows or hears.
  - Automated reasoning: to answer questions and draw conclusions using stored information.
  - Machine learning: To adapt to new circumstances and to detect and extrapolate patterns.
  - Computer vision: To perceive objects.
  - Robotics to manipulate objects and move.

Intelligent System Should do:

- **How can we make computer based systems more intelligent?**
- **In practical terms, intelligent systems:**
  - Should have the ability to *automatically* perform tasks that normally require a human expert.
  - Should have more *autonomy*; less requirement for human intervention or monitoring.
  - Should have *Flexibility* in dealing with variability in the environment in an appropriate manner.
  - Are *easier* to use: able to understand what the user wants from limited instructions.
  - Can improve their performance by learning from experience.

Can we build hardware as complex as the brain?

- **How complicated is our brain?**
  - A neuron, or nerve cell, is the basic information processing unit
  - Estimated to be on the order of 10^{12} neurons in a human brain
  - Many more synapses (10^{14}) connecting these neurons
  - Cycle time: 10^{-3} seconds (1 millisecond)
- **How complex can we make computers?**
  - 10^{6} or more transistors per CPU
  - Supercomputer: hundreds of CPUs, 10^{9} bits of RAM
  - Cycle times: order of 10^{-8} seconds
- **Conclusion**
  - **YES**: we can have computers with as many basic processing elements as our brain, but with
    - Far fewer interconnections (wires or synapses) than the brain
    - Much faster updates than the brain
  - **But** building hardware is very different from making a computer behave like a brain!

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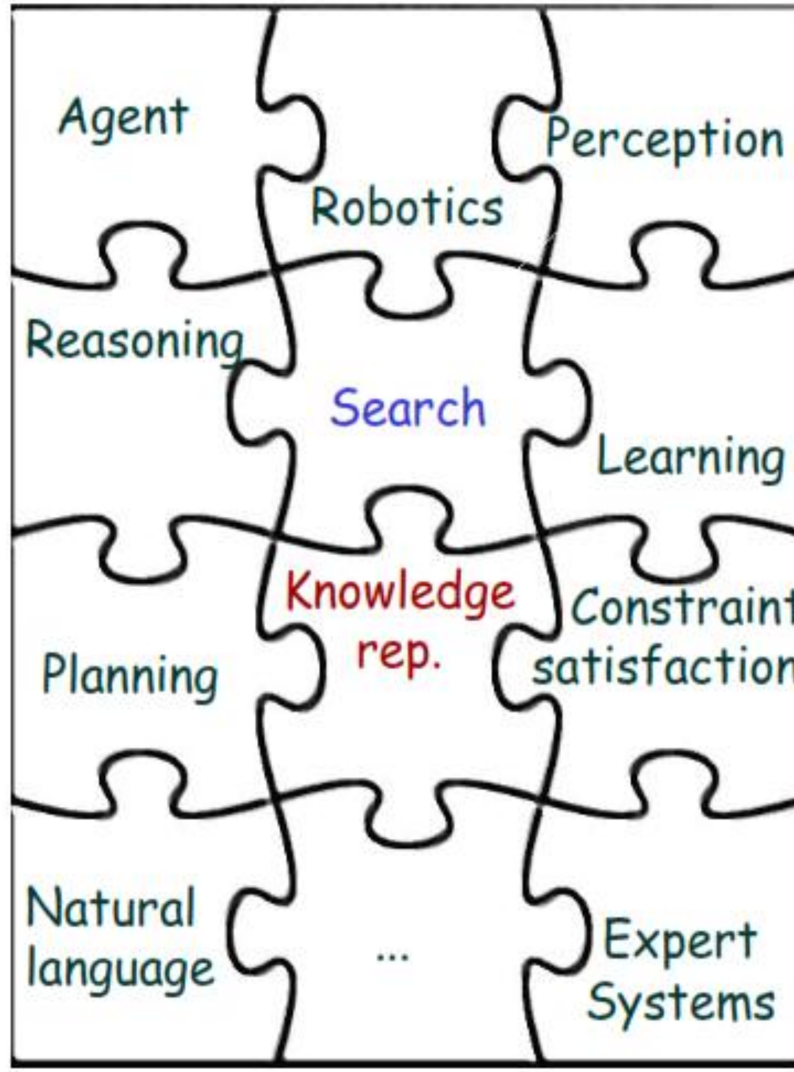
Must an Intelligent System be Foolproof?

- **A "foolproof" system is one that never makes an error:**
  - Types of possible computer errors
    - Hardware errors, e.g., memory errors
    - Software errors, e.g., coding bugs
    - "Human-like" errors
  - Clearly, hardware and software errors are possible in practice
  - What about "human-like" errors?
- **An intelligent system can make errors and still be intelligent**
  - Humans are not right all of the time
  - We learn and adapt from making mistakes
- **Conclusion:**
  - **NO**: intelligent systems will not (and need not) be foolproof

Main Areas of AI

- Knowledge representation (including formal logic)
- Search, especially heuristic search (puzzles, games)
- Planning
- Reasoning under uncertainty, including probabilistic reasoning
- Learning
- Agent architectures
- Robotics and perception
- Natural language processing



Examples of AI Application systems:

- Game Playing
- Autonomous Planning & Scheduling
- Natural Language Understanding
- Pattern Recognitions
- Robotics
- Automated theorem proving
- Web search Engines

Agent

Review: What is AI?

Views of AI fall into four categories:

Thinking humanly	Thinking rationally
Acting humanly	Acting rationally

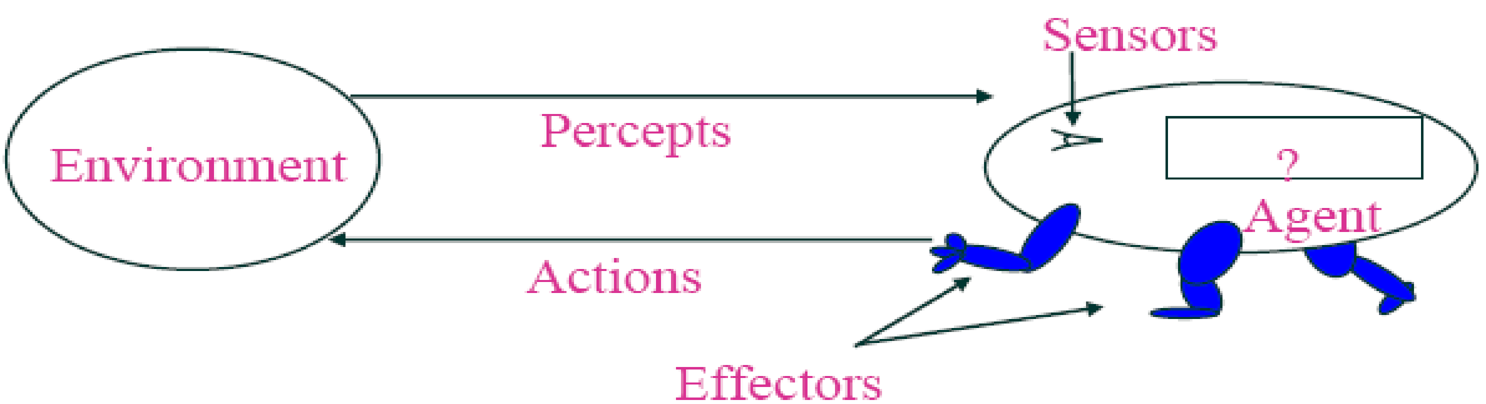
We will focus on "acting rationally"

Acting rationally: rational agent

- Rational behavior: doing the right thing
- The right thing: which is expected to maximize goal achievement, given the available information.

What is an Agent?

- in general, an entity that interacts with its environment
  - perception through sensors
  - actions through effectors or actuators



"Autonomous agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realise a set of goals or tasks for which they are designed"

- *(Pattie Maes, MIT Media Lab)*

Examples of Agents

- **human agent**
  - eyes, ears, skin, taste buds, etc. for sensors
  - hands, fingers, legs, mouth, etc. for actuators
    - powered by muscles
- **robot**
  - camera, infrared, bumper, etc. for sensors
  - grippers, wheels, lights, speakers, etc. for actuators
    - often powered by motors
- **software agent**
  - functions as sensors
    - information provided as input to functions in the form of encoded bit strings or symbols
  - functions as actuators
    - results deliver the output

Agents and Their Actions

- a *rational agent* does "the right thing"
  - the action that leads to the best outcome under the given circumstances
- an *agent function* maps percept sequences to actions
  - abstract mathematical description
- an *agent program* is a concrete implementation of the respective function
  - it runs on a specific agent architecture ("platform")
- problems:
  - what is " the right thing"
  - how do you measure the "best outcome"

Performance of Agents

- criteria for measuring the outcome and the expenses of the agent
  - often subjective, but should be objective
  - task dependent
  - time may be important
- **vacuum agent**
  - number of tiles cleaned during a certain period
    - based on the agent's report, or validated by an objective authority
    - doesn't consider expenses of the agent, side effects
      - energy, noise, loss of useful objects, damaged furniture, scratched floor
    - might lead to unwanted activities
      - agent re-cleans clean tiles, covers only part of the room, drops dirt on tiles to have more tiles to clean, etc.

Rational Agent

- selects the action that is expected to maximize its performance
  - based on a performance measure
  - depends on the percept sequence, background knowledge, and feasible actions
- a rational agent is not omniscient
  - it doesn't know the actual outcome of its actions
  - it may not know certain aspects of its environment
- rationality takes into account the limitations of the agent
  - percept sequence, background knowledge, feasible actions
  - it deals with the expected outcome of actions

Environments

- determine to a large degree the interaction between the "outside world" and the agent
  - the "outside world" is not necessarily the "real world" as we perceive it
    - it may be a real or virtual environment the agent lives in

- in many cases, environments are implemented within computers
  - they may or may not have a close correspondence to the "real world"

Environment Properties

- fully observable vs. partially observable
  - sensors capture all relevant information from the environment
- deterministic vs. stochastic (non-deterministic)
  - changes in the environment are predictable
- episodic vs. sequential (non-episodic)
  - independent perceiving-acting episodes
- static vs. dynamic
  - no changes while the agent is "thinking"
- discrete vs. continuous
  - limited number of distinct percepts/actions
- single vs. multiple agents
  - interaction and collaboration among agents
  - competitive, cooperative

Structure of Intelligent Agents

- **Agent** = Architecture + Program

- **architecture**
  - operating platform of the agent
    - computer system, specific hardware, possibly OS functions

- **program**
  - function that implements the mapping from percepts to actions
  - live in artificial environments where computers and networks provide the infrastructure

emphasis in this course is on the *program* aspect, not on the *architecture*

PEAS Description

Performance Measures	used to evaluate how well an agent solves the task at hand
Environment	surroundings beyond the control of the agent
Actuators	determine the actions the agent can perform
Sensors	provide information about the current state of the environment

PEAS: Taxi Driver Agent

- **Example: Agent = Taxi driver**
  - Performance measure: Safe, fast, legal, comfortable trip, maximize profits
  - Environment: Roads, other traffic, pedestrians, customers
  - Actuators: Steering wheel, accelerator, brake, signal, horn
  - Sensors: Cameras, sonar, speedometer, GPS, odometer, engine sensors, keyboard

Agent Programs

- the emphasis in this course is on programs that specify the agent's behavior through mappings from percepts to actions
  - less on environment and goals
- agents receive one percept at a time
  - they may or may not keep track of the percept sequence
- performance evaluation is often done by an outside authority, not the agent
  - more objective, less complicated
  - can be integrated with the environment program

Skeleton Agent Program

- basic framework for an agent program

```
function SKELETON-AGENT(percept) returns action
  static: memory

  memory  := UPDATE-MEMORY(memory, percept)
  action  := CHOOSE-BEST-ACTION(memory)
  memory  := UPDATE-MEMORY(memory, action)

return action
```

Look it up!

- simple way to specify a mapping from percepts to actions
  - tables may become very large
  - almost all work done by the designer
  - no autonomy, all actions are predetermined
    - with well-designed and sufficiently complex tables, the agent may appear autonomous to an observer, however
  - learning might take a very long time
    - so long that it is impractical
    - there are better learning methods

Table Agent Program

- agent program based on table lookup

```
function TABLE-DRIVEN-AGENT(percept) returns action
  static: percepts// initially empty sequence*
          table   // indexed by percept sequences
                  // initially fully specified

  append percept to the end of percepts
  action    := LOOKUP(percepts, table)

return action
```

* Note:the storage of percepts requires writeable memory

Agent Program Types

- different ways of achieving the mapping from percepts to actions

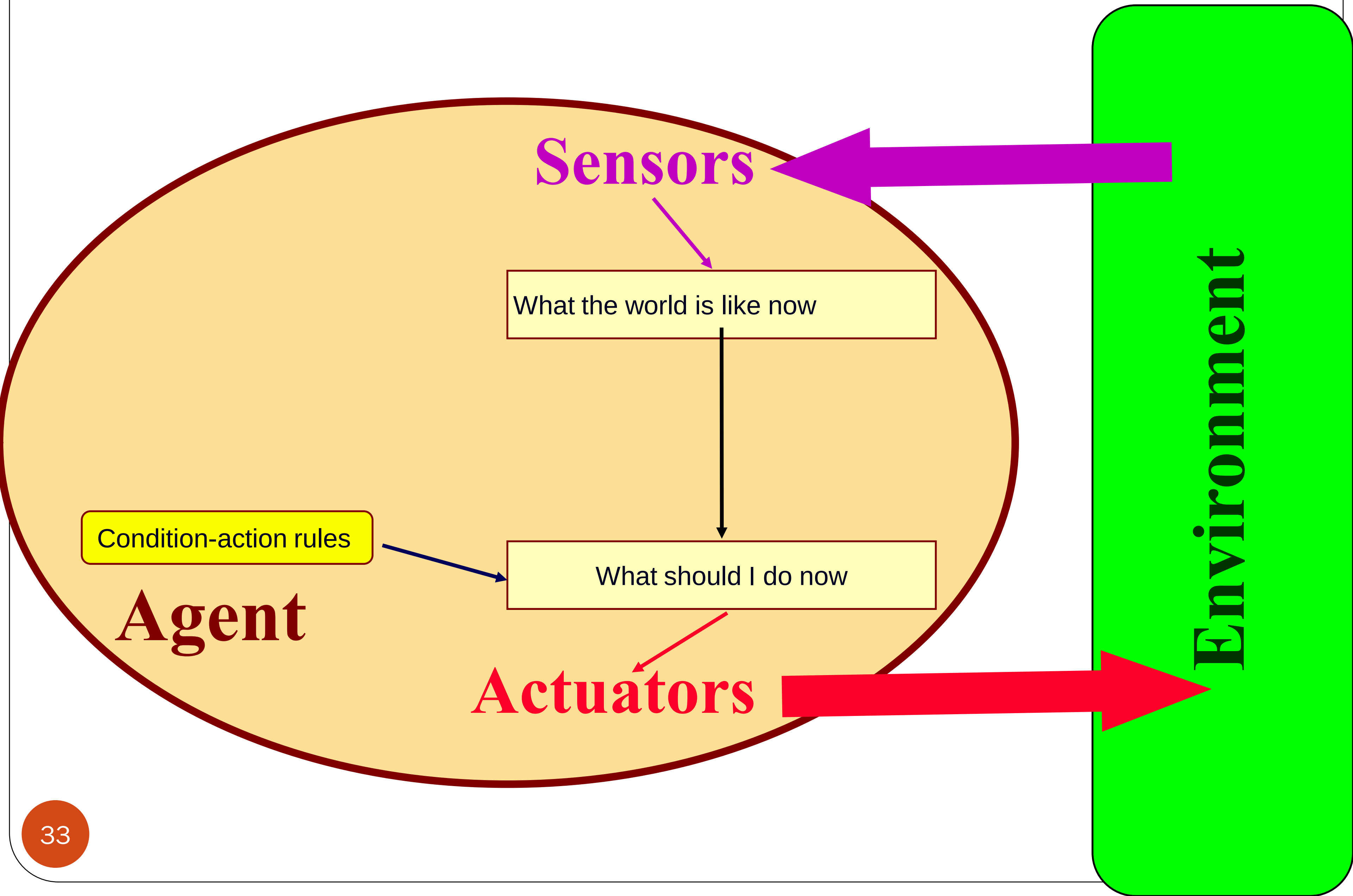
- different levels of complexity
  - simple reflex agents
  - model-based agents
    - keep track of the world
  - goal-based agents
    - work towards a goal
  - utility-based agents
  - learning agents

Simple Reflex Agent

- instead of specifying individual mappings in an explicit table, common input-output associations are recorded
  - requires processing of percepts to achieve some abstraction
  - frequent method of specification is through condition-action rules
    - **if** *percept* **then** *action*
  - efficient implementation, but limited power
    - environment must be fully observable

- Problems
  - Table is still too big to generate and to store (e.g. taxi)
  - Takes long time to build the table
  - No knowledge of non-perceptual parts of the current state
  - Not adaptive to changes in the environment; requires entire table to be updated if changes occur

Reflex Agent Diagram



Reflex Agent Program

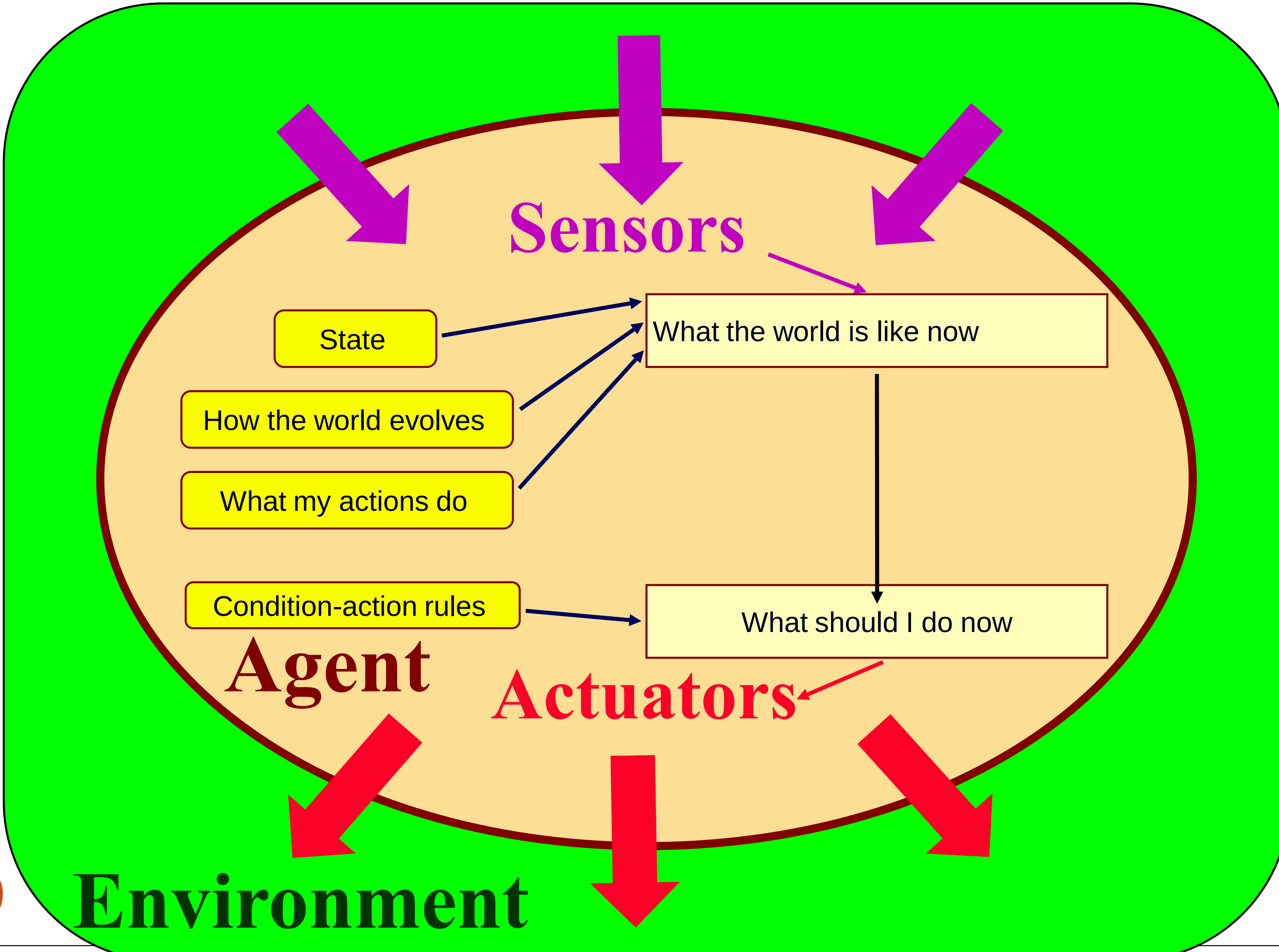
- application of simple rules to situations

```
function SIMPLE-REFLEX-AGENT(percept) returns
  action
  static: rules//set of condition-action rules

  condition     := INTERPRET-INPUT(percept)
  rule          := RULE-MATCH(condition, rules)
  action        := RULE-ACTION(rule)

return action
```

Model-Based Reflex Agent

- an internal state maintains important information from previous percepts
  - sensors only provide a partial picture of the environment
  - helps with some partially observable environments
- the internal states reflects the agent's knowledge about the world
  - this knowledge is called a ***model***
  - may contain information about changes in the world
    - caused by actions of the action
    - independent of the agent's behavior

Model-Based Reflex Agent Diagram



Model-Based Reflex Agent Program

- application of simple rules to situations

```
function REFLEX-AGENT-WITH-STATE(percept) returns action
  static: rules    //set of condition-action rules
          state    //description of the current world state
          action   //most recent action, initially none

  state     := UPDATE-STATE(state, action, percept)
  rule      := RULE-MATCH(state, rules)
  action    := RULE-ACTION[rule]
return action
```

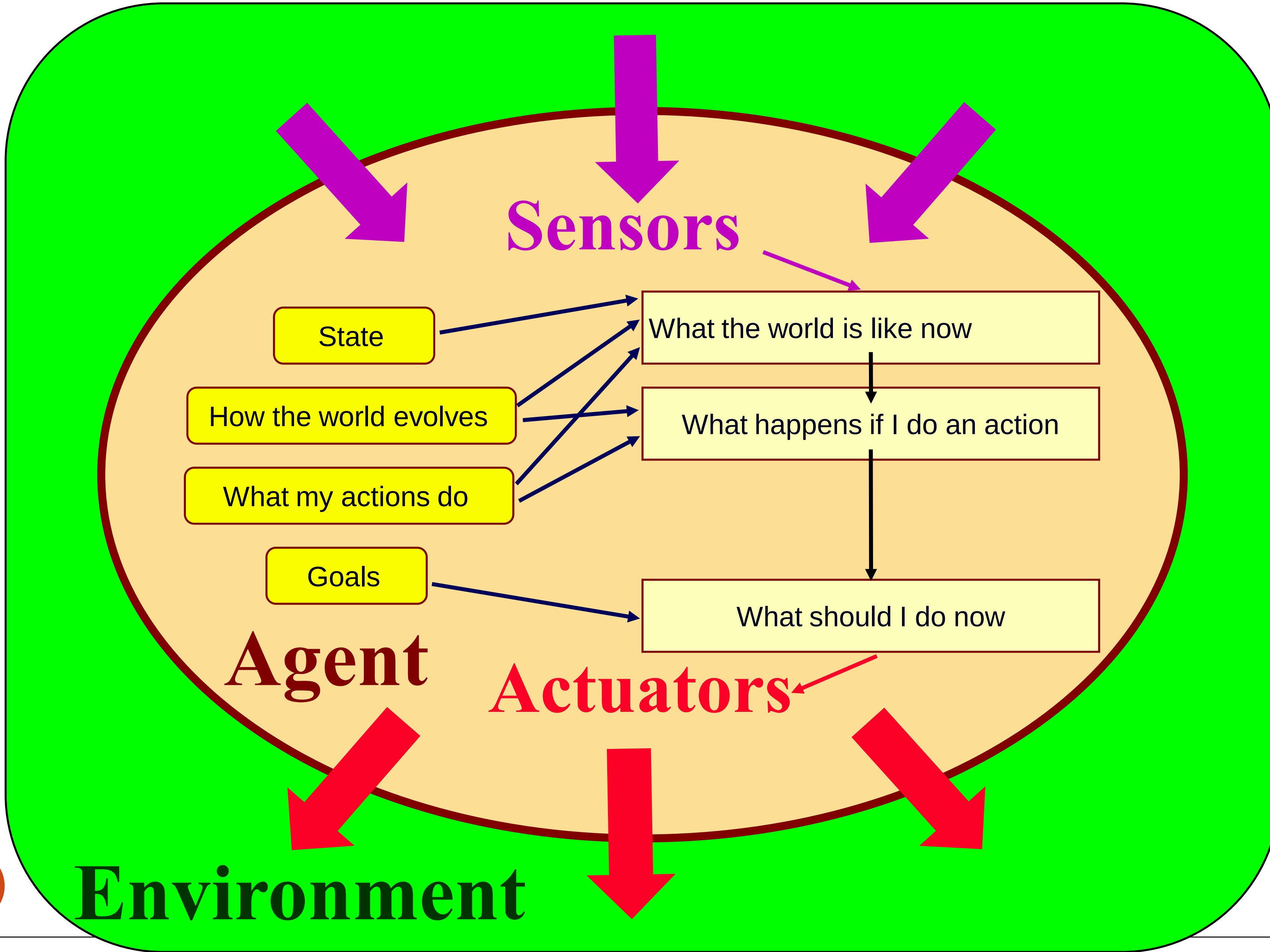
Goal-Based Agent

- the agent tries to reach a desirable state, the *goal*
  - may be provided from the outside (user, designer, environment), or inherent to the agent itself

- results of possible actions are considered with respect to the goal
  - easy when the results can be related to the goal after each action
  - in general, it can be difficult to attribute goal satisfaction results to individual actions
  - may require consideration of the future
    - what-if scenarios
    - search, reasoning or planning

- very flexible, but not very efficient

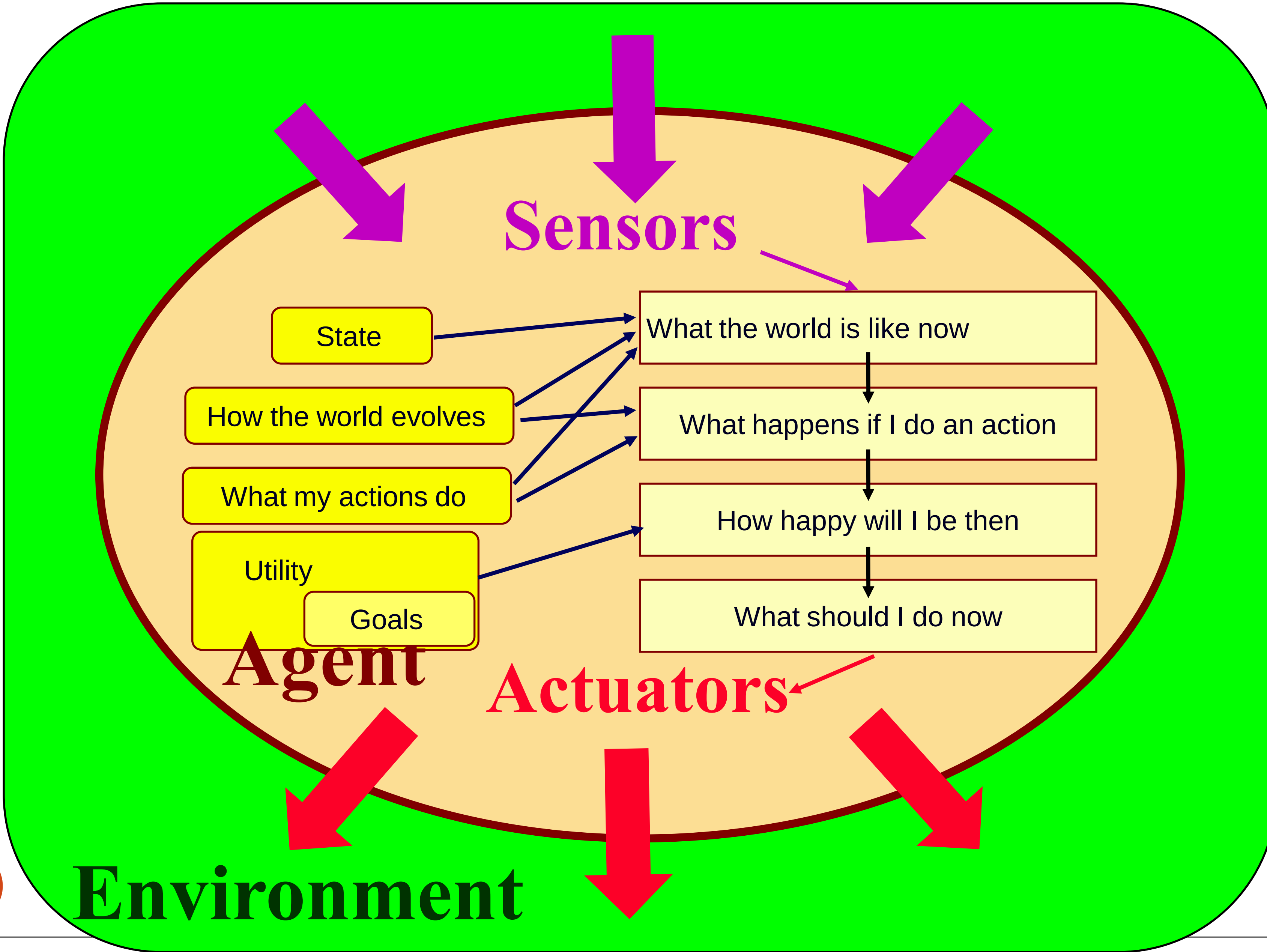
Goal-Based Agent Diagram



Utility-Based Agent

- more sophisticated distinction between different world states
  - a utility function maps states onto a real number
    - may be interpreted as "degree of happiness"
  - permits rational actions for more complex tasks
    - resolution of conflicts between goals (tradeoff)
    - multiple goals (likelihood of success, importance)
    - a utility function is necessary for rational behavior, but sometimes it is not made explicit

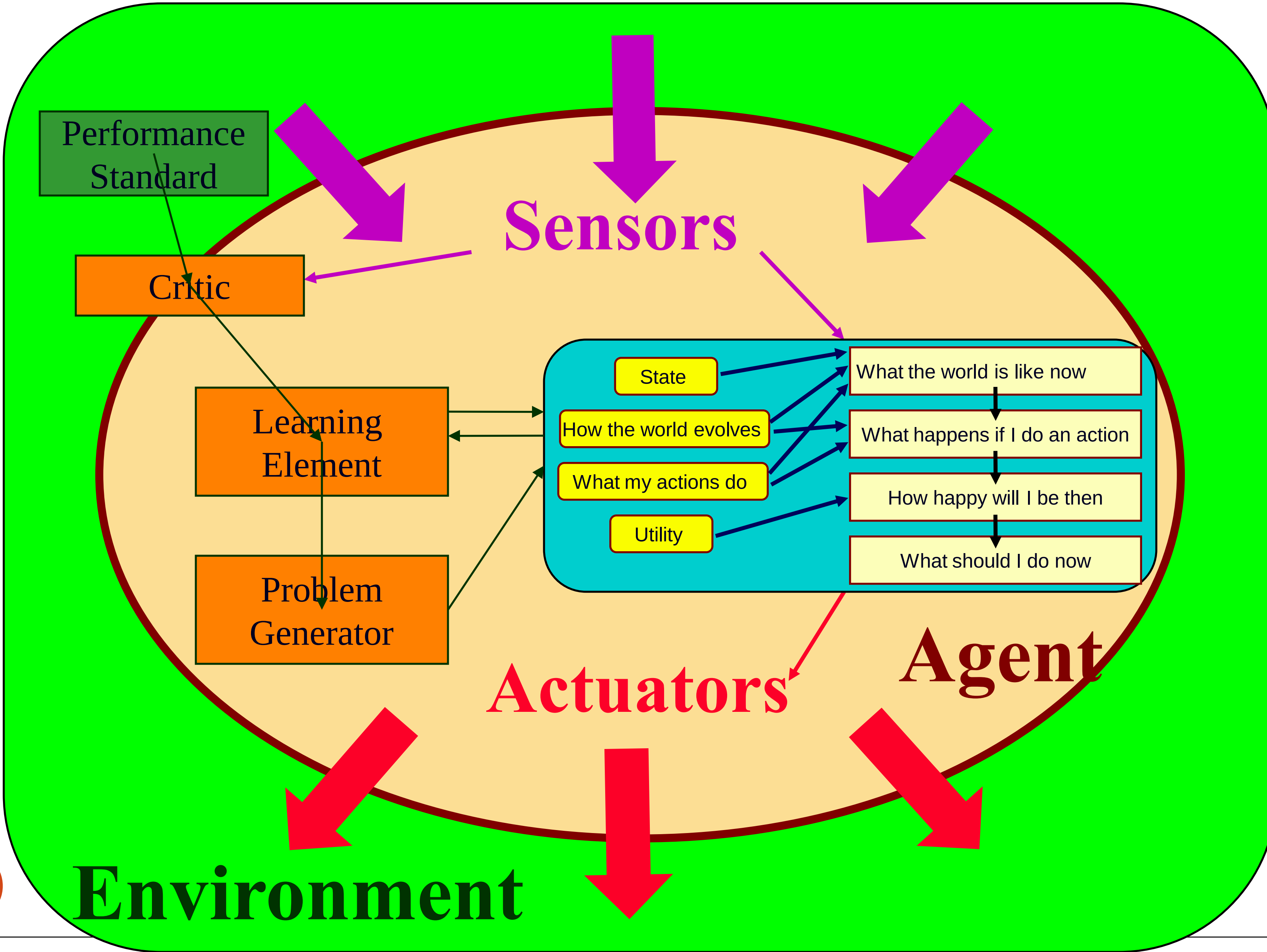
Utility-Based Agent Diagram



Learning Agent

- performance element
  - selects actions based on percepts, internal state, background knowledge
  - can be one of the previously described agents
- learning element
  - identifies improvements
- critic
  - provides feedback about the performance of the agent
  - can be external; sometimes part of the environment
- problem generator
  - suggests actions
  - required for novel solutions (creativity

Learning Agent Diagram



Chapter Summary

- What is an AI
- agents perceive and act in an environment
- ideal agents maximize their performance measure
  - autonomous agents act independently
- basic agent types
  - simple reflex
  - reflex with state
  - goal-based
  - utility-based
  - Learning
- some environments may make life harder for agents
  - inaccessible, non-deterministic, non-episodic, dynamic, continuous