Natural Computation and Behavioral Robotics

Genetic versus Adaptive Intelligence

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Lecture 7

Overview

- What is Genetic Intelligence ?
- What is Adaptive Intelligence ?
- How does each one produces “intelligence” ?
- How does “memory” affects each one ?
- How does “knowledge” is encoded in them ?
- When should we prefer to use each one ?

Genetic “Intelligence”

- A property is hard-coded in a DNA sequence that constitutes a gene or “**genotype**”.
- Each gene corresponds to a different functionality or a “**phenotype**” (result when “decoding” each gene).
- Genes are mutated and combined during a reproduction process (⇒ combined “functionalities”).
- Best (combined) functionalities survive, i.e. their corresponding genes get to survive too.
- Multiple mutation-selection cycles produce optimal populations (⇒ best-fitted solutions to a problem).

Genetic Algorithms (G.A.)

Basic idea:

1. Encode a problem's parameters into artificial "genes" of *linearly* encoded information (strings of bits or characters).
2. Implement software functions for "mutation" and "selection" steps of evolution cycle.
3. Set a large pool of "genes" in some initial (random) values and let the population "evolve" towards an optimal solution after a large number of cycles.

Implementing G.A.

- Initialize: produce a large number of genes with random values as the starting population
- Crossover: take two genes and use one part of the first and the remaining part from the second to produce a new “offspring”
- Mutation: change a specific point in a single gene, from one value to another
- Fitness: compute how well a “gene” works for the current environment
- Update: eliminate “bad” genes and keep the rest for the next evolution cycle (⇒ “selection” process in Nature)

Adaptive Intelligence

Basic idea:

1. Use a very simple ("dumb") and very low-level functionality as the starting base.
2. Use a small or large "memory" pool to store previous action-result associations as structured "past experience" or "knowledge".
3. Exploit gained "knowledge" to constantly "adapt" and improve future decisions.

Adaptive Systems

- They start off with no experience or "hard-coded" knowledge about their environment.
- First few decisions are usually very "bad", but they "learn" to behave better over time.
- Actions leading to good results are preferred over actions leading to bad results.
- Over time, they develop optimal behavior for the current environment (⇒ "survive").

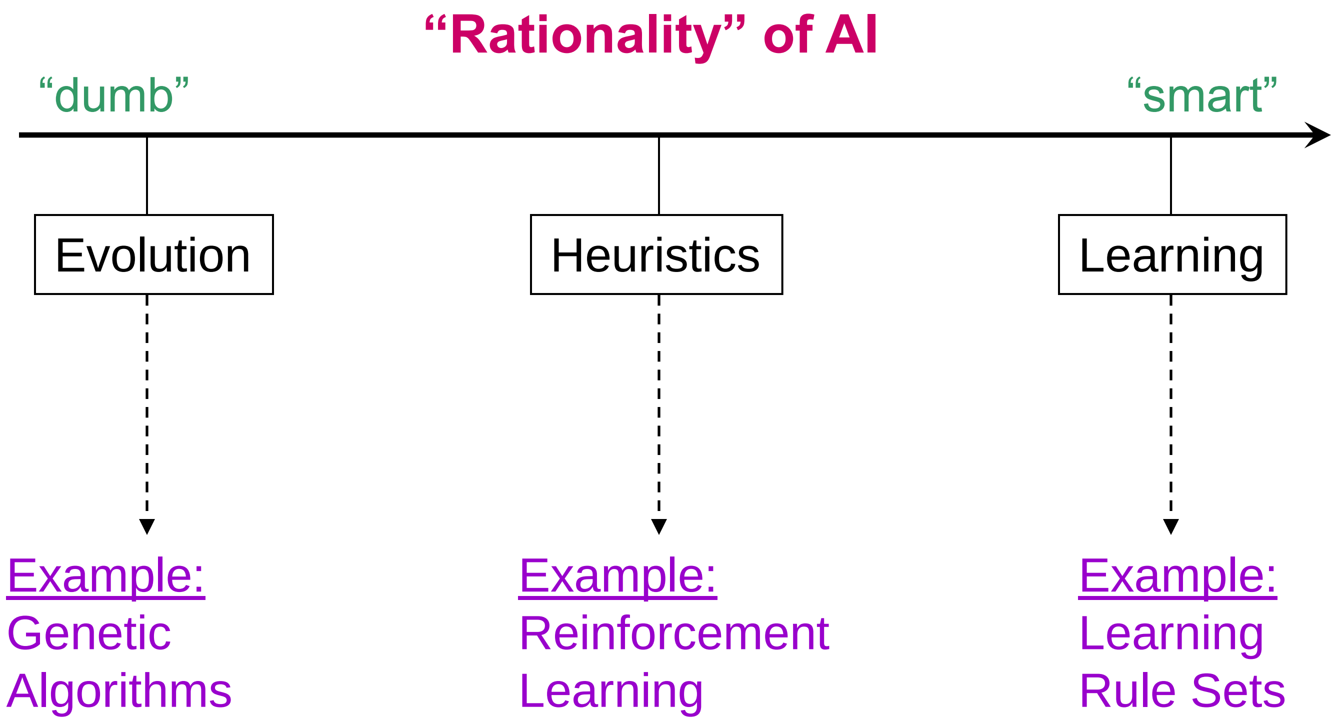
Implementing Adaptive Behavior

- Organized approach: “*Reinforcement Learning*”
- Also: “Temporal Difference Learning” (more general).
- Implement adaptive decision-making by employing an iterative update rule for “gain”.
- Adaptiveness includes:
  - “Reference Points”: past cases of good decisions
  - “Experimentation”: how often to ignore experience
  - “Forgetfulness”: how quickly to forget experience
- Although simple, they often result in erratic or even chaotic behavior (see: logistic equation, fractals).

Genetic versus Adaptive Agents

	Genetic AI	Adaptive AI
Start-off:	Large population	Small population
Optimize:	Evolution of “good” genes	Learn from their mistakes
Advantages:	Effective for static environments	Adapt to dynamic environments
Pitfalls:	Genes do not become “smarter”	Must survive until they get “smart”

Degrees of Rationality



“Rationality” of AI

“dumb”

“smart”

Evolution

Heuristics

Learning

Example:
Genetic
Algorithms

Example:
Reinforcement
Learning

Example:
Learning
Rule Sets

Food for thought

- When should we use Genetic-based AI ?
- When should we use Adaptive-based AI ?
- Do animals use Genetic or Adaptive AI ?
- How does the "memory" factor is implemented in each one of them ?
- How does this "memory" affects and/or propagates the optimality in each case ?

P.C. – Readings

- Tom Mitchell, “Machine Learning”,McGrawHill, 1997. [see: ch.9, ch.13]
- John L. Casti, “Reality Rules II: Picturing the World in Mathematics – The Frontier”, John Wiley & Sons, 1997. [see: ch.7]
- Sergui Hart, “Adaptive Heuristics”, Journal of Economic Literature, Dec.2004
- Mikhael Shor, “Learning to Respond: The Use of Heuristics in Dynamic Games”, Vanderbilt Univ., Jun.2004