Natural Computation and Behavioral Robotics

Genetic versus Adaptive Intelligence

Harris Georgiou – xgeorgio@di.uoa.gr

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 ($\Rightarrow$ combined "functionalities")
- Best (combined) functionalities survive, i.e. their corresponding genes get to survive too
- Multiple mutation-selection cycles produce optimal populations ($\Rightarrow$ best-fitted solutions to a problem)

Genetic Programming

Basic idea:

1. Encode a problem's parameters into artificial "genes" of 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 Genetic Algorithms

- 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 ($\Rightarrow$ "selection" process in Nature)

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Adaptive Intelligence

Basic idea:

1. Use a very "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 "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 ($\Rightarrow$ "survive")

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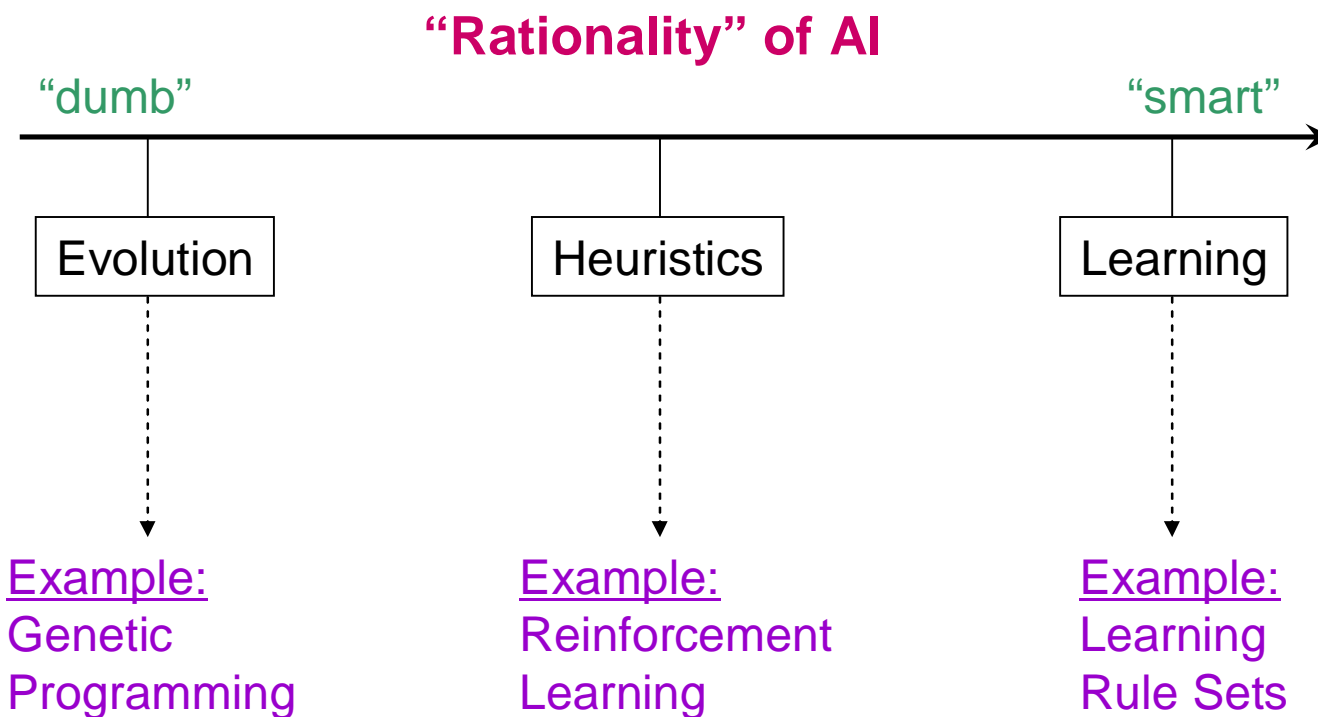
Implementing Adaptive Behavior

- Generic approach: "*Reinforcement Learning*"

- Implement adaptive decision-making by employing an <u>iterative update rule</u> 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)

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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"

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Degrees of Rationality

"Rationality" of AI

"dumb"   "smart"

Evolution	Heuristics	Learning

Example:
Genetic
Programming

Example:
Reinforcement
Learning

Example:
Learning
Rule Sets

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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 <u>implemented</u> in each one of them ?

- How does this "memory" affects and/or <u>propagates</u> the optimality in each case ?

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P.C. – Readings

- Tom Mitchell, "Machine Learning",McGrawHill, 1997. [see: ch.9, ch.13]

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- 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