The Artificial Life Roots of Artificial Intelligence

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Outline

- AI and AL
- Delineating the field
- Behavior Systems
- Emergent Behavior
- Emergent Functionality
- Open Issues

AI and AL

- Traditional AI focuses on higher-order cognitive activity like expert problem solving.
- Subgroup stress embodied intelligence → artificial life (also Bottom-Up AI, Animat approach, Behavior-based AI, Animal Robotics).
- Aim of paper: review the approach and identify major unresolved issues.

Delineating the field: The Subject Matter

- The study of behavior.
- Focus: what makes behavior intelligent and adaptive? How does behavior emerge?
- Behavior: a regularity observed in the interaction between the characteristics and processes of a system and the characteristics and processes of an environment.
- Intelligent behavior: maximizes preservation of the system in its environment.

Delineating the field: The Methodology

- Computational models: process oriented descriptions in terms of data structures and algorithms.
  - Contents of data structures are modified over time.
  - Phenomena can be observed.

- Artificial models: construct a physical device whose physical behavior gives rise to phenomena.
  - Design and implementation of the device components provide a way to theorize about the real-world phenomena they reproduce.

Delineating the field: The influence of Biology

- Study of intelligent behavior with a strong biological orientation.
- Cognitive and intelligent abilities are equated to the capacity of the living.
- Classical AI defines intelligence in terms of knowledge which is maximally applied.
- Behavior-oriented approach defines intelligence in terms of observed behavior and self-preservation.
  - Dynamic learning and adaptation to a changing environment.
- Cooperation and competition between agents at all levels (agents, behaviors and components).

Behavior Systems

- Units causing the behavior of an agent are not directly observable.
- Building blocks (sensors, neurons, networks of neurons) work together and interact with the environment to establish behavior.
- Same components may dynamically be involved in many different behaviors.
- Difficult to bridge the gap between neurology and psychology.

Behavior Systems

- Behavior systems are basic units. Consist of components (sensors, body parts), networks, termporary states.
- Functionality: something that the agent needs to achieve (also task, goal, competence)
- Behavior: regularity in the interaction between an agent and its environment.
- Mechanism: principle or technique for establishing a particular behavior.
- Component: physical structure or process used to implement a mechanism.

Guidelines for Behavior Systems' Design

- Suggested by current tendencies, still an art form.
- Make behavior systems as specific as possible.
  - Specificity-generality tradeoff.
- Exploit the physics.
  - Ex. In obstacle avoidance a robot equipped with bumpers.
- No symbol processing for sensing and acting.
  - Difficult to decode sensory data into symbols, the grounding problem.
- Complex behavior may originate from simple mechanisms.
  - Situated cognition: intelligence is the result of simple situation-specific agent/environment mechanisms that are strongly adapted to moment-to-moment decision making.

Different Approaches to the Behavior-Based Approach

- Neural networks approach.
- Algorithmic approach
  - collection of behaviors described as finite-state machines organized in a subsumption architecture.
- Circuit approach
  - Network of simple circuit components that perform Boolean operations. Outputs of one component may input into another.
- Dynamics approach
  - Collection of processes, each establishes a relationship between quantities (sensory signals, action parameters or internal states). Not subsumption architecture, each behavior is active all the time, and the effects are added to obtain the resulting action.

Emergent Behavior

- Existent behavior systems in interaction with each other and the environment can show side effects.
- May or may not be useful.
- In nature complexity buildup is preferred through evolution.
- Unpredictable, side effects are not always beneficial.
- An advantage for an agent operating independently in the world, only way the agent can autonomously increase its abilities.
- Most basic form of emergent behavior is through side effects (i.e. follow the wall as a side effect of a wall-seeking behavior and an obstacle avoiding behavior).

Emergence

- From the observer's perspective: new categories are needed to describe the underlying regularity that are not needed to describe previous behaviors.
- Uncontrolled variable: the agent cannot directly control it.
- Invisible variable: the agent cannot sense it.
- From the components' perspective (those implicated in the emergent behavior):
  - Regularity involves an uncontrolled variable.
  - Regularity involves only invisible variables (a stricter requirement).

Emergent Functionality

- Emergent behavior that is useful.
- Supervised learning and reinforcement learning are constructivist techniques – minimize error or reinforcement, need a teacher.
- Selectionism: genetic algorithms through mutation or recombination.
- Only very preliminary work.
- Target towards many diverse and adaptive behavior systems in competition.

Open Issues

- Knowledge-oriented v.s. behavior-oriented: researchers on both sides have claimed the other approach is irrelevant.
- Many believe the symbolic level exists as an independent level, causally influenced by and causally influencing the dynamics level.
- Difficulty to achieve formalization and theory formation.
- Optimality of behavior.
- Self-preservation of the agent.