Behavior-based Robotic

Lecture 4

Key aspects of the behavior-based methodology:

- Situatedness:
  - The robot is an entity situated and surrounded by the real world (or real virtual world); Brooks: "*World is its best model*"
- Embodiment:
  - A robot has a physical presence (a body with limitations, non-holonomic robot), or virtual presence (a software body with limitations)
- Emergence:
  - Intelligence arises from the interactions of the robotic agent with its environment. It is not the property of either the agent or the environment in isolation but is rather a result of the interplay between them

Issues in Behavior-based Paradigm

- ***Grounding in reality***
  - Symbol grounding problem; Brooks: "*The world is its own best model*" Problem of using simulators
- ***Ecological dynamics***
  - An agent is immersed in a highly dynamic environment. Evolutionary processes shape agents to fit their ecological niche
- ***Scalability***

Definitions

- *Individual behavior*:
  - A stimulus-response pair for a given environmental setting that is modulated by attention and determined by intention
- *Attention*:
  - prioritizes tasks and focuses sensory resources and is determined by the current environmental context
- *Intention*:
  - Determines what set of behaviors should be active based on the robotic agent's internal goals and objectives

Definitions (cont.)

- *Emergent behavior*:
  - The global observed behavior; a consequence of the interaction of the active individual behaviors
- *Reflexive behavior* (purely reactive behavior)
  - Behavior that is generated by hardwired reactive behaviors with tight sensor-effector coupling.

Animal Behavior

- *Ideas*
  - Animal behavior defines intelligence
  - Proof that intelligent behavior is possible
  - Can provide models that can be used to create intelligent machines
  - Biological studies are not necessary viewed as constraining for robots;
- *Problems*
  - Biological hardware is different
  - Our knowledge of the functioning of the biological hardware is often inadequate

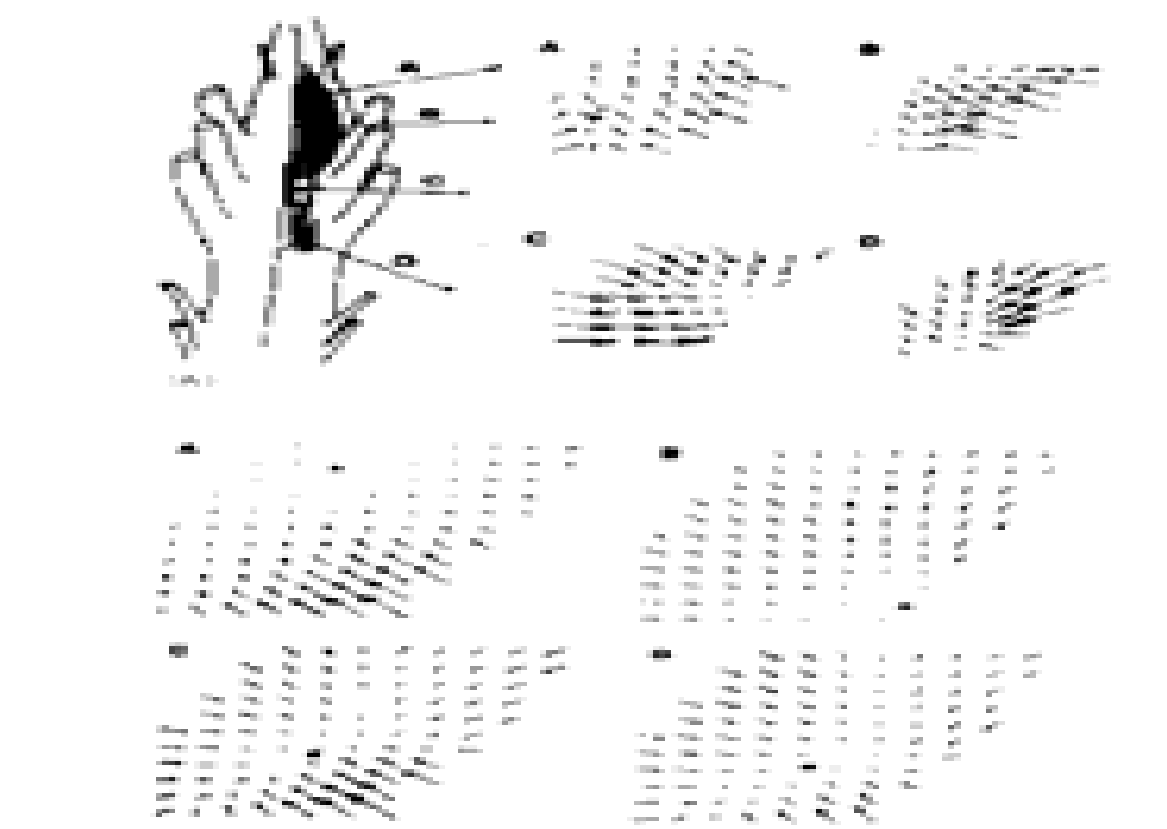
Animal behavior Studies

- *Neuroscience*
  - The study of the nervous system's anatomy, physiology, biochemistry, and molecular biology
- *Psychology*
  - The study of mind and behavior
- *Ethology*
  - The study of animal behavior in natural conditions

Evidence from Neuroscience

- *Many specialized small systems in animal kingdom have been analyzed*:
  - bat sonar
  - wiping reflex in frogs
  - cockroach locomotion
- *Evidence exists that vector calculation is used in some areas in the brain*.
- Evidence exists that the *planning* in the central nervous system translates into establishing equilibrium points that implicitly specify the desired motion.

Force fields in frog spinal cord



Some neuroscience theories

- *Schema theory*
  - Philosophical model; Immanuel Kant
  - Neurological schema theory (C.1910)
  - A schema is the basic unit of behavior from which complex actions can be constructed.
- *Neural networks theory*
  - Basic model (1943) (McCulloch&Pitts)
  - Perceptron (1959) (Minsky&Papert)
  - Backpropagation (1985) (Rummelhart, Hinton & Williams

Psychology

- *Robotics is currently using ideas and theories of human psychology* that researchers in psychology no longer accept as valid.
- i.e.recycling of old ideas of psychology in the field of robotics;
- controversial ideas and theorems can be used in robotics

Some paradigms in psychology

- *Behaviorism*, (1910)
  - Main idea: Everything is "Stimulus and Response"
  - B.F.Skinner
- *Gestalt psychology*, (1947)
  - Main idea: “Pure behaviorism is limited; there exists levels of organization above the sensation“
- *Ecological psychology*, (1979)
  - Main idea: "Things are perceived in terms of the opportunities they afford." Concept of affordances.
  - The observer and the environment complement each other.

Some paradigms in psychology

- *Cognitive psychology*, (1975)
  - Cognition: the activity of knowing: the acquisition, organization, and use of knowledge;
- *Main ideas*:
  - classical behaviorism explains only animal behavior
  - A series of subsystems (pipeline) processes the environmental information:
  - stimulus⇒attention ⇒ perception ⇒ thought processes ⇒ decision ⇒ response

Psychophysics

- Sensory psychophysics was the first to *relate stimulation intensity to perception*.
- Weber e Fechner developed physical laws that described the relationship between
  - a stimulus's physical intensity and its intensity as perceived by an observer.

Behaviorism

- Behaviorism emerged upon psychology in the early 1910s. *It discarded all mentalistic concepts such as sensation, perception, image, desire, purpose, thinking and emotion*.
- **Behavior** *was defined by observation only* (Watson, 1925); data stem from observing what an organism did or said. *Everything was cast in terms of stimulus response*.
- The main advantage of this approach was making the field more scientifically objective, moving away from the use of introspection as the primary basis for the study of mind.

Gestalt Psychology

- **Gestalt psychology** (Kohler, 1974) emphasizes physics *drawing from tradition of sensory psychophysics while broadening behaviorism's basis*. This form of psycology inverted behaviorism somewhat, concerning itself heavily with ***sensor input*** (predominantly visual) and *how behavior arises as a direct consequence of the structure of the physical environment interacting with the agent itself*.
- The term ***gestalt*** was derived from the German where it *referred to form or shape as an attribute*.

Ecological Psychology

- **Ecological psychology**, as advocated by J. Gibson (1979), demanded a *deep understanding of the environment* in which the organism was situated and *how evolution affected its development*. The notion of **affordance** provides a means for explaining perception's roots in behaviors.
- This psychological theory says that *things are perceived in terms of the opportunities they afford an agent to act*.

Affordance

- *All actions are a direct consequence of sensory pickup*. This results from the tuning by evolution of an organism situated in the world to its available stimuli. **Significant assertions** (Gibson, 1979) include:
  - *The environment is what organism perceive*. The physical world differs from the environment, namely, it is more than the world described by physics.
  - *The observer and the environment complement each other*.
  - *Perception of surfaces is a powerful means of understanding the environment*.

Cognitive Psychology

- Cognitive psychology emerged, paralleling the advent of computer science, defining **cognition** as "*the activity of knowing*" (Neisser, 1976), based on
  - acquisition,
  - organization and
  - use of knowing.
- Information processing and computational models of the mind began to play an ever increasing role.
- Behaviorism was relegated to the role of explaining animal behavior and became less influential in studying human intelligence.
- Unifying methods of explaining the relationship between action and perception were developed under the banner of cognitive science (Neisser, 1976).

Ethology I

- Ethology is the study of animal behavior in its natural environment (Lorenz e Tinbergen).
- Tinbergen considered ethological studies to focus on four primary areas of behavior: **causation**, **survival value**, **development** and **evolution**.
- Animal behavior itself can be roughly classified into three major categories: **reflexes**, **taxes** and **fixed action pattern** (McFarland (1981).

Ethology II

- **Reflexes**
  - *rapid, automatic, involuntary responses to a stimuli*
- **Taxes**
  - chemotaxis (positive/negative tropism towards a certain chemical),
  - *behavioral responses that orient the animal* toward (positive tropism) or away (negative tropism) from a stimulus, examples:
  - phototaxis (positive/negative tropism towards light)
- **Fixed-action patterns**
  - *Time-extended response patterns triggered by a stimulus but persisting for longer than the stimulus itself*

Reflexes

- *Reflexes are rapid automatic involuntary responses triggered by a certain environmental stimuli*.
- The reflexive responses persists only as long as the duration of the stimulus. Further, the response intensity is correlated with the stimulus's strength.
- Reflexes are used for **locomotion** and other **highly coordinated activities**.
- Certain escapes behaviors involve reflexive action that results in rapid contraction of specific muscles.

Taxes

- Taxes are *behavioral responses that orients* the animal toward or away from a stimulus (attractive or aversive).
- Taxes occur in response to *visual, chemical, mechanical and electromagnetic phenomena* in a wide range of animals.
- Depending on the specific physical quantity involved in sensing we term the response as **chemotaxis**, **phonotaxis**, **tropotaxis**, **kliniotaxis**, **phototaxis**, etc...

Fixed-action Pattern

- *Fixed-action patterns are time-extended response patterns triggered by stimulus* but persisting for longer than the stimulus itself.
- *The intensity and duration of the response are not governed by the strength and duration of the stimulus*, unlike a reflexive behavior.
- Fixed-action patterns may be motivated, unlike reflexes, and may result from a much broader range of stimuli than those that govern a simple reflex.

Motivated Behaviors

- **Motivated behaviors** *are governed not only by environmental stimuli but also by the internal state of the animal*.

Ecological niche

- *The status of an animal in its community, in terms of its relations to food and enemies, is generally called its niche*.
- *Evolution* has modeled animals to fit their niche.
- To be *self sufficient*, an agent must exhibit behavioral stability and market viability.
  - Behavioral stability implies that the agent does not succumb to irrecoverable debt of any vital resource
  - Market viability amounts to pleasing the robot's employer

Ecological niche of robots

- *If the roboticist intends to build a system that is autonomous and can successfully compete with other environmental inhabitants, that system must find a stable niche or it (as an application) will be unsuccessful*.
- For robots to be commonplace, they must find the ecological niches that allow them to survive and/or dominate their competitors, whether they be mechanical or biological.

Robot behavior in Reactive systems

- In reactive control
  - *perception and action are tightly coupled* typically in the context of motor behaviors,
  - to produce *timely robotic response* in dynamic and unstructured worlds
  - *without the use of intervening abstract representation* or time history.

Purely reactive robotic system

- *Behaviors serve as the basic building blocks for robotic actions*.
- Use of *explicit abstract representational knowledge is avoided* in the generation of a response.
- *Animal models of behavior* often serve as a basis for these systems.
- These *systems are inherently modular* from a software design perspective.

Example:

- Task of going from one classroom to another
- Issues
  - route (shortest route)
  - safety (avoiding obstacles, avoiding teacher X)
  - speed (time optimal, or if with person Y, as slow as possible)
  - means of going (walking, elevators/lifts, conveyor belts etc)
  - opportunism (cafeteria/pub effect, event Z)
  - cultural and social conventions (meeting a very important person)
- Observation: a simple task is actually a very complex one!

Behavior-based Robotics

- *Behavior-based robotics grew out of the recognition that planning, no matter how intentioned, is often waste of time*.
- *Behavior-based robotic systems provide a means for a robot to navigate in an uncertain and unpredictable world without planning, by endowing the robot with behaviors* that *deal with specific goals independently and coordinating them in a purposeful way*.

BBS

- Behaviors are the underlying module of the system
- *Behavioral decomposition*
  - Systems consist of sequential modules achieving independent functions

Robotic Behavior

- Generate a motor response from a given perceptual stimulus.
- Basis in *biological studies*
  - Serves as inspiration for design

Behavior vs Action

- **Behavior**
  - *Based on dynamic process*
    - Operating in parallel
    - Lack of a central control
    - Fast couplings between sensors and motors
  - Exploiting emergence
    - Side-effects from combined processes
    - Using properties of environment
  - Reactive

- **Action**
  - Discrete in time
    - Well-defined start and end points
    - Allows pre- and postconditions
  - Avoidance of side effects
    - Only one action or few actions at a time
    - Conflicts are undesired and avoided
  - Deliberative

Reactivity

- Behaviors serve as building blocks for actions
- Abstract representation avoided
- Often modeled after animal behaviors
- Inherently modular

Stimuli

- *Presence of stimulus is necessary but not sufficient in behavior-based robot*.
- *Stimulus must reach threshold value before response is generated*.

Representation

- Behaviors can be *represented/stored in a network*, with relationships between them
- Strength multiplier, or gain, can turn off behaviors or increase response

Properties of Behaviors

- Behaviors are feedback controllers
- Behaviors achieve specific tasks/goals (e.g., avoid-others, find-friend, go-home)
- Behaviors are typically executed in parallel/concurrently
- Behaviors can store state and be used to construct world models/representation
- Behaviors can directly connect sensors and effectors (i.e., take inputs from sensors and send outputs to effectors)
- Behaviors can also take inputs from other behaviors and send outputs to other behaviors (this allows for building networks)
- Behaviors are typically higher-level than actions (go-home rather than turn-left-by-45-degrees)
- Behaviors are typically closed-loop but extended in time
- When assembled into distributed representations, behaviors can be used to look ahead but at a time-scale comparable with the rest of the behavior-based system