

Animal Behavior

- **Relevant Biological Disciplines**
 - **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 settings
- **Inspirations => Models**
 - Some computational ideas are merely inspired by biology
 - Others are detailed models of biological analogs
 - **Neurons** => Neural networks
 - **Conditioning** => Reinforcement learning
 - **Evolution** => Genetic algorithms
 - **Economics** => Classifier systems

- Short Term Memory

- Short term memory (STM) is also called **working memory**
- It is used for tasks requiring only **temporary storage** (i.e., working space)
- It lasts **from seconds to minutes**
- It is limited in capacity
- Information is stored in up to about 7 ± 2 **chunks** (but what are chunks?)

- Long Term Memory

- Long term memory (LTM) is the **catch-all term** for everything else
- LTM time-scale is **from hours to years**
- LTM recall accuracy is worse than that of STM
- It is considered **almost limitless in capacity**
- The **hippocampus** is involved in **transfer of STM to LTM**

- Abstract Neural Models

- Examples:

- schema theory

- connectionist models (i.e., neural nets)

- Schemas

- Schemas are the *basic unit of behavior* from which complex actions can be constructed.

- Schemas consists of the knowledge of how to **act** or **perceive** and the computational process that enact it.

- Schemas are patterns of action as well as a **patterns for action**

- Also used as **behaviors** or **primitives**.

• Neural Networks

- Neural networks are based on the **McCulloch-Pitts** neuron model (1943)
- Perceptron model (Rosenblatt, 1958), gained great popularity quickly
- Analyzed (Minsky & Papert, 1969), promptly lost popularity for two decades
- Subsequent rise of research and practical applications
- NNs are computational tools; they compute... (what?)

- **Types of NNs**

- NNs compute **statistical associations** between inputs and outputs
- NNs are used in two typical ways:
 - as ***implicit tools***, **black boxes** that are **trained** to perform a specific task
 - as ***explicit tools***, that are **designed to compute a well-defined function**;
 - these are usually called “statistical neural networks”
- **Critical aspects:**
 - topology (single versus multi layer, **recurrent**)
 - **weights**

• Perceptrons

- Perceptrons are the **simplest** type of an NN, with known limitations
- Perceptron networks have an **input layer** (set of input nodes) and an **output**:

• Psychology

- The science of psychology has several branches relevant to robotics
- **Sensory psychophysics**: the study of the quantitative relationship between **stimuli** and **perception**
- Psychology proposes different theories:
 - **Behaviorism**: no representation
 - **Gestalt psychology**: incoming perception is organized into complete **units**

• Ethological Psychology

- Founded by J.J. Gibson (1979)
- Views organisms as situated in an environment, and perceiving it
- Key concept: **Affordances**, opportunities to act
- Motion provides **optic flow-based** perception
- Information (structure):
 - is inherent in the environment,
 - is inherent in **light**,
 - is detected by the organism

• Cognitive Psychology

- Cognitive psychology grew out of the emerging science of computation
- It is based on information processing and computational models
- Cognitive subsystems **process information** systematically
 - attention,
 - perception,
 - decision,
 - response,
 - etc.
- **Processing** proceeds:
 - **bottom-up** from *stimuli*
 - **top-down** from *intentions and expectations*

• Ethological Behavior Classes

- **Reflexes:** rapid automatic involuntary responses triggered by specific environmental stimuli
 - e.g., duckling following,
 - knee jerk.
- **Taxes:** drives away from or toward a specific stimulus (e.g., phonotaxis in crickets, chemotaxis in ants)
- **Fixed-action patterns:** time-extended responses (sequences of actions) that persist longer than the stimulus itself (e.g., *egg rolling*)

• Ethological Niches

- A niche is the collection of relevant factors that impact an organism/animal.
- *“The status of an animal in its community, in terms of its relations to food and enemies.”*
- **Evolutionary niche:** the influence of evolutionary pressure
- **Environmental niche:** the influences of habitat, climate, food sources, population density, etc.

- **Robotic Examples**

- A great many examples of *biologically-modeled robots* exist today
- They include models of
 - perceptual systems
 - motor systems
 - “simple” behaviors
 - compound behaviors
 - group and social behaviors

- **Modeling Perception**

- Fly and hoverfly vision
- Cricket audition
- Antennal lobes
- Haptics

- **Models of Motor Control**

- Frog reaching and wiping
- Six-legged walking
- Swinging/brachiation

- **Cockroach robots**

- MIT,
- Case Western,
- IS Robotics,
- Northeastern...

- **Primate Brachiation**

- Japan

- **Modeling Behaviors**

- Taxes:

- Phototaxis
 - Phonotaxis (crickets, bees)
 - Chemotaxis (ants, lobsters)
 - Hippocampus-based navigation
 - Bee dance

- **Robot Cricket**

- B. Web (UK)
 - Model phonotaxis accurately
 - Synthetic sensors sufficient for task
 - First implemented with a LEGO robot!

- **Chemotaxic Robots**

- Plume-following lobster robots (Case Western)

- **Robotic Honeybee**

- Study communication via dance
- Role of sound essential

- **Modeling Compound Behaviors**

- Foraging (finding and collecting food)
- Cockroach behaviors (multi-modal sensing and feeding)
- **Predator / prey** strategies

- **Foraging and Flocking**

- Mataric '90 (MIT)

Modeling Group Behavior

- Pursuit-evasion
- Foraging
- Herding
- Online Resource:
 - Dorigo's papers on ants
 - an ant colony optimization page