• Reactive model based on biological organisms

• 2 areas that contributed to the model:
  1. Ethology: Study of animal behavior
  2. Cognitive psychology: Study of how people think and represent knowledge

• 2 opposing perspectives on biologic approaches:
  1. Animal behavior does not indicate how to do something mechanically
     – Planes do not flap their wings argument
  2. If behavior is observed (hence possible), it can be implemented
     – Existence proof argument

• Biologic approaches based on open world assumption

• Very simple organisms can exhibit seemingly complex behavior

• Inherent problem for mechanical beings is how to define intelligence
  – Dealt with via abstractions

• Agent: Abstract intelligent system that is self-contained and independent

• Intelligence can be defined in terms of computational theory
  – Marr’s theory:
    1. Level 1: Existence proof
       * Observation is proof it can be implemented
       * Many agents can share (have in common) intelligence at this level
    2. Level 2: Identification of behavioral components
       * Id individual behaviors that together combine to achieve the intelligence
       * Each is a black box
       * Organisms can share behaviors at this level
    3. Level 3: Implementation
       * Deals with inner workings of the individual black boxes
       * Implementation usually different from agent to agent

  – Robotics approach focuses on Levels 1 and 2
    * Biological simulation of Level 3 is not the goal of robotics
Reactive Model: Biological Foundations - Behavior

- Behavior: Mapping of sensory inputs to patterns of actions that perform a task

- Are basic building blocks of natural intelligence

- 3 general types:
  1. Reflexive (stimulus-response):
     - Hard-wired
  2. Reactive:
     - Initially learned
     - Later compiled into reflexive-type behavior
     - Can be modified by conscious thought
  3. Conscious:
     - Deliberative; requires conscious thought

- Reactive paradigm concerned with reflexive behavior

- Types of reflexive behaviors:
  1. Reflex:
     - Response proportional to stimulus strength, and lasts only as long as stimulus
  2. Taxis:
     - Response orients agent with respect to stimulus
  3. Fixed-action pattern:
     - Response lasts longer than stimulus
Reactive Model: Biological Foundations - Behavior (2)

• Methods of acquiring behavior (Lorentz and Tinbergen):

  1. Innate:
     – Hardwired
     – Computationally easy
  2. Sequence of innate behaviors:
     – State resulting from one behavior is stimulus for next in sequence
     – Hardwired
  3. Innate with memory:
     – Behavior is innate, but must be customized with respect to organism’s environment
  4. Learned

• Behavior can be triggered by internal state

• Complex behavior can be result of interaction of multiple simple behaviors
Reactive Model: Biological Foundations - Innate Releasing Mechanisms

- IRM (Lorentz and Tinbergen):
  - Trigger that activates a behavior

- Releaser:
  - Boolean flag that controls whether a behavior can be triggered

  ![Diagram of IRM](attachment:image.png)

  - General releaser algorithm:
    releaser trigger;
    while (TRUE) {
      trigger = senseStimulus();
      if (trigger == PRESENT)
        doBehavior();
    }

  `senseStimulus()` acts as a filter for a given stimulus

  - Releasers can be compound

    releaser food, hungry;
    while (TRUE) {
      food = senseFood();
      hungry = checkStateHunger();
      if ((food == PRESENT) && (hungry == PRESENT))
        feed();
    }
Reactive Model: Biological Foundations - Innate Releasing Mechanisms

(2)

- Releasers can be part of behavior sequence, each set by a behavior and enabling the next in the sequence

releaser food, hungry, nursed;
while (TRUE) {
    food = senseFood();
    hungry = checkStateHunger();
    child = checkStateChild();
    if (hungry == PRESENT)
        searchForFood();
    if ((hungry == PRESENT) && (food == PRESENT))
        feed();
    if ((hungry == !PRESENT) && (child == PRESENT))
        nurse();
    if (nursed == PRESENT)
        sleep();
}

Note: Assumes each behavior in sequence lasts for a fixed amount of time, round-robin style
– Place high-priority behaviors first (self-preservation):

releaser food, hungry, nursed, predator;
while (TRUE) {
  food = senseFood();
  predator = sensePredator();
  hungry = checkStateHunger();
  child = checkStateChild();
  if (predator == PRESENT)
    flee();
  if (hungry == PRESENT)
    searchForFood();
  if ((hungry == PRESENT)&&(food == PRESENT))
    feed();
  if ((hungry == !PRESENT)&&(child == PRESENT))
    nurse();
  if (nursed == PRESENT)
    sleep();
}

May cause erratic behavior
Reactive Model: Biological Foundations - Innate Releasing Mechanisms

- To preclude behavior dangerous to organism, inhibit low-priority behaviors in presence of survival ones:

releaser food, hungry, nursed, predator;
while (TRUE) {
    food = senseFood();
    predator = sensePredator();
    hungry = checkStateHunger();
    child = checkStateChild();
    if (predator == PRESENT)
        flee();
    else {
        if (hungry == PRESENT)
            searchForFood();
        if ((hungry == PRESENT) && (food == PRESENT))
            feed();
        if ((hungry == !PRESENT) && (child == PRESENT))
            nurse();
        if (nursed == PRESENT)
            sleep();
    }
}

Reactive Model: Biological Foundations - Innate Releasing Mechanisms

(5)

– To allow survival, response can outlast stimulus (fixed-action pattern):

```plaintext
releaser food, hungry, nursed, predator;
while (TRUE) {
    food = senseFood();
    predator = sensePredator();
    hungry = checkStateHunger();
    child = checkStateChild();
    if (predator == PRESENT)
        for (time = T; time > 0; time--)
            flee();
    else {
        if (hungry == PRESENT)
            searchForFood();
        if ((hungry == PRESENT) && (food == PRESENT))
            feed();
        if ((hungry == !PRESENT) && (child == PRESENT))
            nurse();
        if (nursed == PRESENT)
            sleep();
    }
}
```

Note: This overrides fixed time intervals for each behavior

- Behaviors can execute concurrently and independently
  - Interactions may result in
    1. Equilibrium:
       * Behaviors balance each other
    2. Dominance:
       * One overrides the others
    3. Cancellation:
       * Cancel each other, allowing other behaviors to execute
Reactive Model: Biological Foundations - Perception

- Must be able to perceive environment in order to react to it
- Action-perception cycle:

  **Action-Perception Cycle**

1. Actions change environment, and therefore agent’s perception of world
2. Agent senses environment
3. New perceptions used to generate actions (plan based, reactive)

- Different than hierarchical paradigm because planning not required
- Percepts play 2 roles:
  - To release behavior
  - To acquire more specific percepts in order to accomplish a behavior (*selective attention*)
- Action-oriented perception: Percepts filtered
Reactive Model: Biological Foundations - Gibson’s Ecological Approach

• Foundation of reactive approach

• Contends that perception evolved to support action
  – Cannot be studied in independently from environment and survival behavior
  – Referred to as ecological model

• Based on concept of affordance
  – *Perceivable* potentialities of environment for an action
  – External stimulus of an IRM (but not a trigger, *per se*)
  – Require no memory, inference, or interpretation - directly perceivable
  – Execute quickly
Reactive Model: Biological Foundations - Neisser’s Perceptual Systems

- Affordances not sufficient by themselves:
  - Some tasks require memory (e.g., recognition)
  - Others interpretation and inference (e.g., problem solving)

- Neisser proposed 2 perceptual systems:
  1. Direct perception
     - Ecological-based
     - Part of brain that evolved early
     - Uses affordances
  2. Recognition
     - Part of brain that evolved later
     - Used for cognitive activities
     - Top-down, model-based perception
Reactive Model: Biological Foundations - Schemas

- Schema: script (pattern) for behavior
- Consists of
  1. Knowledge of how to act and/or perceive
  2. Algorithm to achieve task
- Schema is instantiated in a given situation
- Schema instantiation: instantiated schema
- Arbib’s schema representation of behavior:

Motor Schemas and Behavior

1. Perceptual schema
   - Corresponds to processing of sensory input of behavior
2. Motor schema
   - Corresponds to reactive aspect of behavior
Reactive Model: Biological Foundations - Schemas (2)

- Primitive behavior:

\[
\begin{array}{|c|c|}
\hline
\text{Data} & (\text{none}) \\
\hline
\text{Methods} & \text{perceptual\_schema()} \\
& \text{motor\_schema()} \\
\hline
\end{array}
\]

- Behavior sequence:

\[
\begin{array}{|c|c|}
\hline
\text{Data} & \text{releaser1} \\
& \text{releaser2} \\
& \text{releaser3} \\
& \text{IRM\_logic} \\
\hline
\text{Methods} & \text{behavior1()} \\
& \text{behavior2()} \\
& \text{behavior3()} \\
\hline
\end{array}
\]

- Schemas depend on environment (i.e., may be several schemas that could be chosen):

\[
\begin{array}{|c|c|}
\hline
\text{Data} & \text{environmental\_state} \\
\hline
\text{Methods} & \text{choose\_PS(environmental\_state)} \\
& \text{perceptual\_schema1()} \\
& \text{perceptual\_schema2()} \\
& \text{motor\_schema()} \\
\hline
\end{array}
\]

- Schema theory is computational Level 2

- To model stimulus-response, perceptual schema can pass gain to motor schema
Reactive Model: Biological Foundations - Robotics and Biologic Theory

- Biological principles useful for robotics:

  1. Complex actions should be decomposed into independent behaviors which tightly couple senses and actions. Behaviors are inherently parallel and distributed.

  2. Agent should rely on straightforward Boolean activation methods (IRMs) to simplify control and coordination of behaviors.

  3. Perception should filter sensing and consider only what is relevant to behavior (action-oriented perception) to simplify sensing.

  4. Direct perception (affordances) reduce computational complexity of sensing and permit actions to occur without memory, inference, or interpretation.

  5. Behaviors are independent, but output from one may combine with another, or inhibit another (competing-cooperating)

- Unresolved issues:

  1. How are conflicts between concurrent resolved?

  2. When are memory and knowledge representation required?

  3. How are sequences learned?

- Major difference between biologic organisms and robots is that organic behavior is result of evolution of behaviors that promote survival of species

  Robotic behavior is programmed