CISC 1003 - EXPLORING ROBOTICS

ROBOT CONTROL TYPES

CISC1003

Feedback Control Types

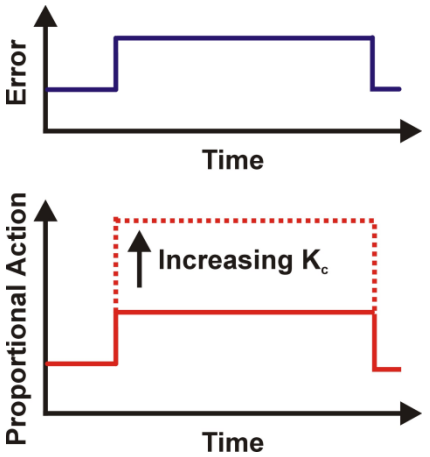
The three most used types feedback control are:

- Proportional control (P)
- Proportional Derivative control (PD)
- Proportional Integral Derivative control (PID)

Proportional Control

- System responds in proportion to the error
  - using both the direction and the magnitude of the error.
- For wall-following robot:
  - Use distance-to-wall to determine the angle and distance and/or speed with which the robot would turn.
- .

http://blog.opticontrols.com/archives/344



Proportional Control

- Gains: The parameters that determine the magnitude of the system's response
  - In control theory
- Damping:
  - The process of systematically decreasing oscillations.
  - A properly damped system => does not oscillate out of control.

Derivative Control

- The controller corrects for the momentum of the system as it approaches the desired state.
  - Relative to the rate the error changes
- When the system is close to the desired state, it needs to be controlled differently than when it is far from it
  - Otherwise, the controller's correction will carry the system beyond the desired state
    - cause oscillations

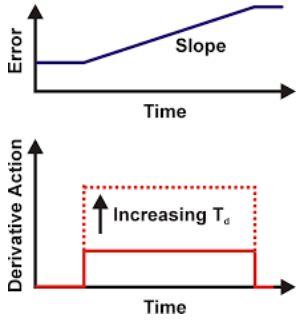
Derivative Control

- Best estimate the future trend of the error, based on the current rate of change

Control - Example

- Robot moving towards a target
- Proportional control:
  - Speed changes based on distance from target
- Derivative control:
  - Speed changes based on current speed of robot
    - The faster it is, the more we will slow it down
      - So it does not hit a wall

Derivative Control



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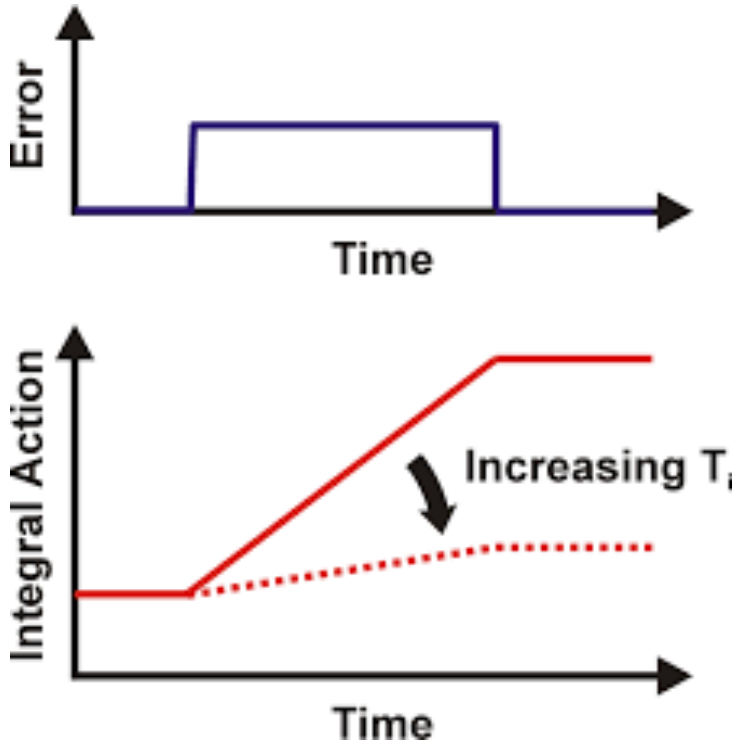
Integral Control

- The system integrates (sums up) these incremental errors over time
  - When reaching a predetermined threshold the system does something to compensate/correct.
    - Once the cumulative error gets large enough
- Example: A robot lawn mower with an error when turning to cut sections of grass.
  - With a system to detect the error, it can compensate for it over time.

Integral Control

- Account for past behavior of system
- Integrates the error over time

Integral Control



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Control - Example

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Control - Example

- Integral control:
  - Speed change based on overall distance from wall
    - If distance was small for a long time => small change required
      - May be good for a wall-following program
    - If distance changes drastically, then overall integral will minimize changes
      - The sum of changes changes less in time
      - Reduce the need to make constant changes to the robot speed
      - Helps overcome inaccurate sampling

Derivative Control Systems

- Proportional Derivative control (PD)
  - Applied in most industrial plants
  - Extremely useful for process control.
- Proportional Integral Derivative control (PID)
  - A combination of proportional P, integral I, and derivative D control terms.

Control Architectures

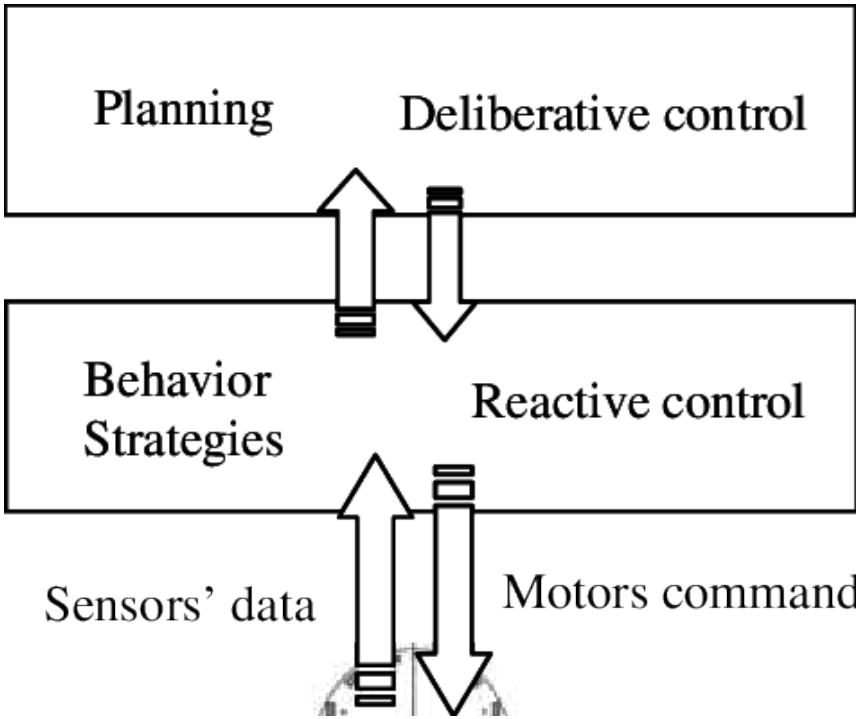
- The controller functions as the robot's brains
  - So robot can be autonomous, achieve its goals.
- The robot can sense multiple things at once.
  - The controller decides what the robot needs to observe.

Control Architectures

- Not all control architectures are the same
- Different capabilities allow for different robot functionality
  - Regardless of which language is used to program a robot, architecture will determine functionality
    - Programming language is just a tool to program robot

Control Architectures

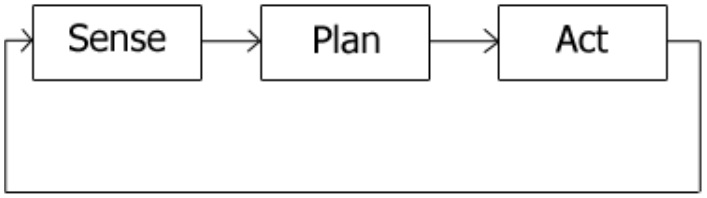
- May include two components:
  - Deliberative Control
  - Reactive Control



https://www.researchgate.net/figure/Hybrid-robot-architecture_fig1_304540754

Deliberative Control

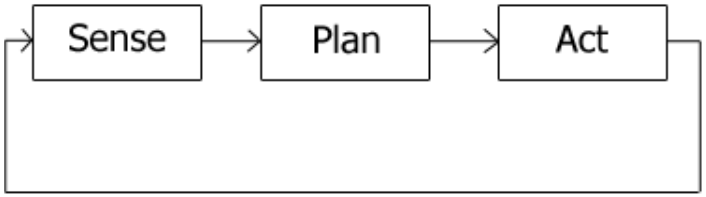
- Planning:
  - The process of looking ahead at the outcomes of the possible actions
  - searching for the sequence of actions that will reach the desired goal.
- Search:
  - An inherent part of planning.
  - involves looking through the available representation “in search of” the goal state.



https://en.wikipedia.org/wiki/Robotic_paradigm

Deliberative Control (cont.)

- Deliberative, planner-based architectures involve three steps that need to be performed in sequence:
  - Sensing (S)
  - Planning (P)
  - Acting (A), executing the plan.



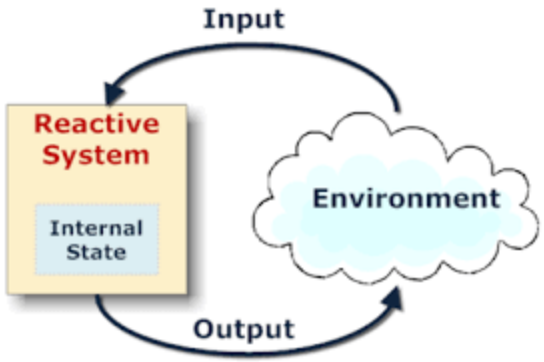
- These steps need to be performed in sequence

Reactive Control

- Reactive rules are similar to reflexes
  - innate responses that do not involve any thinking.
- How to design a good reactive system?
  - Keep it simple and straightforward
  - Define robot states:
    - Situations that can be detected by the robot's sensors
  - Each unique state should trigger only one unique robot action

Reactive Control

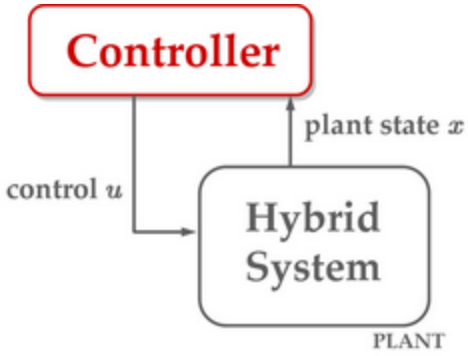
- Reactive rules must support parallelism
  - To handle checking multiple sensors.



http://www.reactive-systems.com/c-automatic-test-generation.html

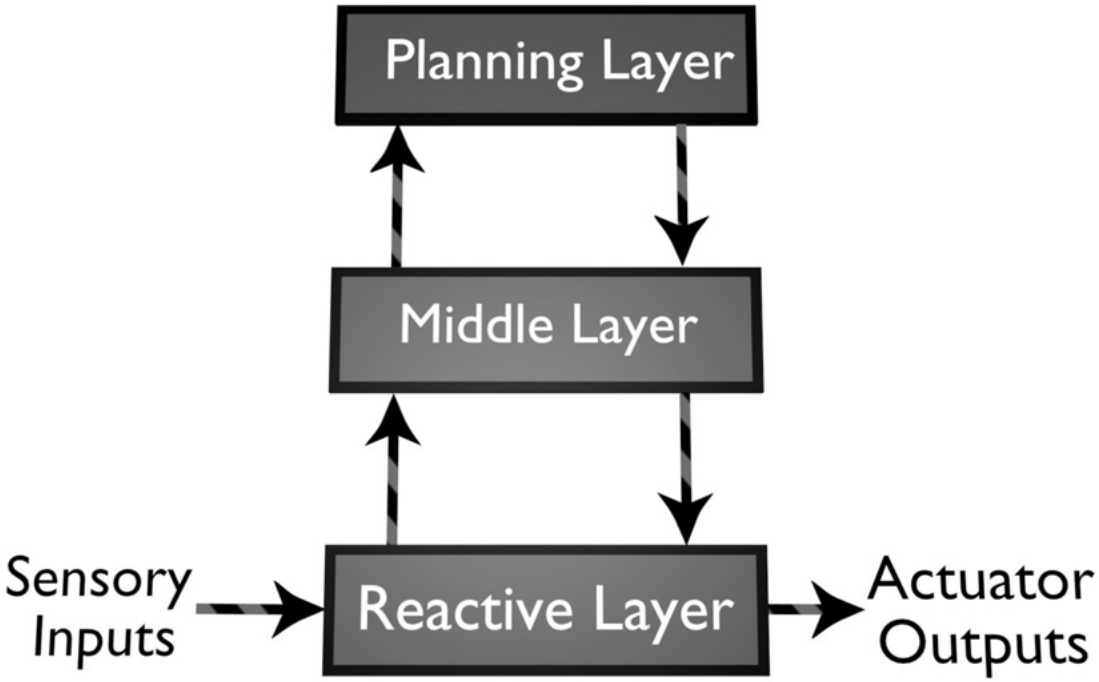
Hybrid Control

- Involves the combination of reactive and deliberative control
  - within a single robot control system
- Components:
  - Planner
  - Middle layer that links the layers together
    - (by issuing commands).
  - Reactive layer



http://people.ee.ethz.ch/~cohysys/control.php

Hybrid Control



BEHAVIOR BASED CONTROL

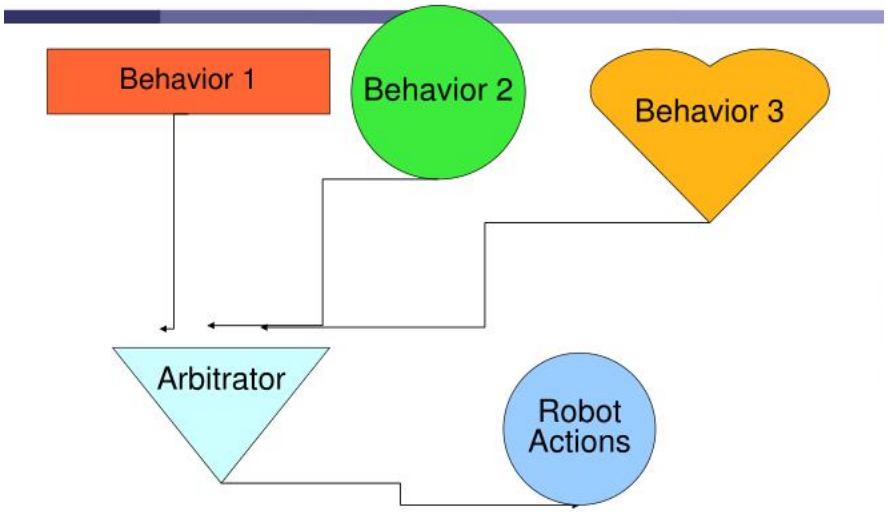
Behavior-Based Control

- Behavior-based control (BBC) involves the use of "behaviors" as modules for control.
- Behaviors achieve and/or maintain complex goals.
  - A homing behavior:
    - Achieves the goal of getting the robot to the home location.
  - A wall-following behavior:
    - maintains the goal of following a wall.

Behavior-Based Control

- Behaviors take time to execute and are not instantaneous.
- Requires constantly monitoring the sensors and other behavior status variables.

Behavior-Based Control



https://www.slideserve.com/mostyn/behavior-based-control

CASE STUDY – *BOIDS* ALGORITHM BY CRAIG REYNOLDS

Algorithm - *Boids* by Craig Reynolds

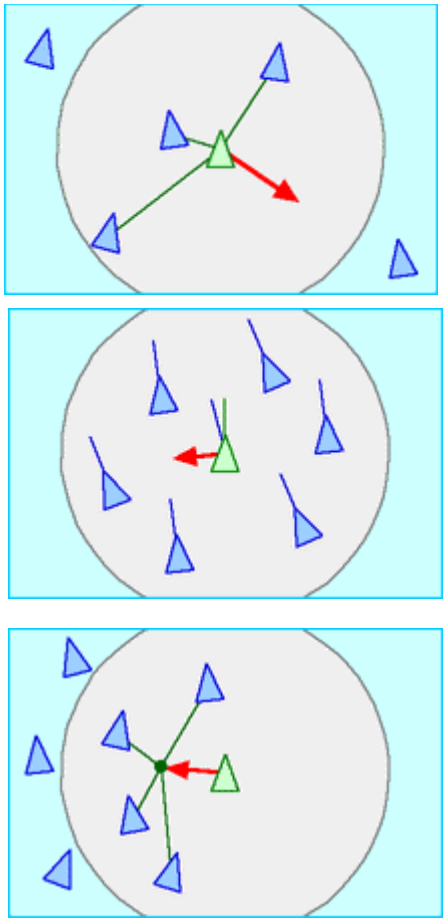
- Algorithmic for coordinated animal motion
  - Models steering behaviors
    - for animated flocking creatures.
  - Allowed individual elements to navigate their digital environments in a “life-like” manner
    - with strategies for different actions:
      - seeking, fleeing, wandering, arriving, pursuing, evading, path following, obstacle avoiding, etc.

Algorithm - *Boids* by Craig Reynolds (cont.)

- System has multiple characters
  - each steering according to simple locally-based rules,
- Surprising levels of complexity emerge
  - the most famous example being Reynolds' "boids" model for "flocking"/"swarming" behavior.

Algorithm - *Boids* by Craig Reynolds (cont.)

- Simple steering behaviors:
  - Separation:
    - avoid crowding neighbors
  - Alignment:
    - steer towards average heading of neighbors
  - Cohesion:
    - steer towards average position of neighbors



https://www.red3d.com/cwr/boids/

Algorithm - *Boids* by Craig Reynolds (cont.)

- An animated short featuring the boids model called **Stanley and Stella in: Breaking the Ice** was created
  - Boids video

Swarm Robotics

- 1000 Robots Swarm

- From local rules to global behaviors


QUESTIONS