

Robot Architectures and Design

CSCI 420-04 Robotics



WILLIAM & MARY

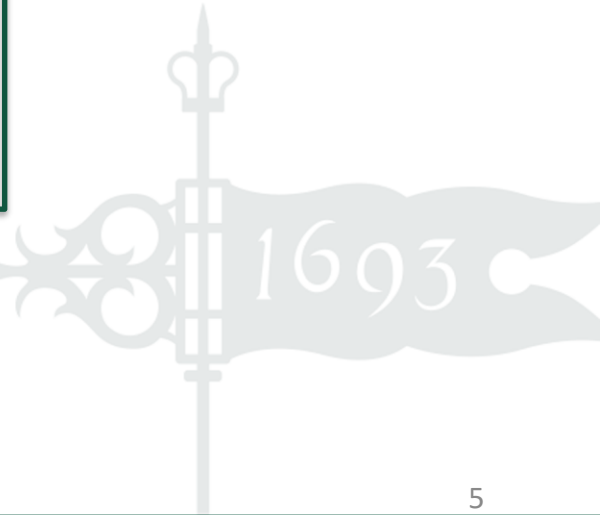
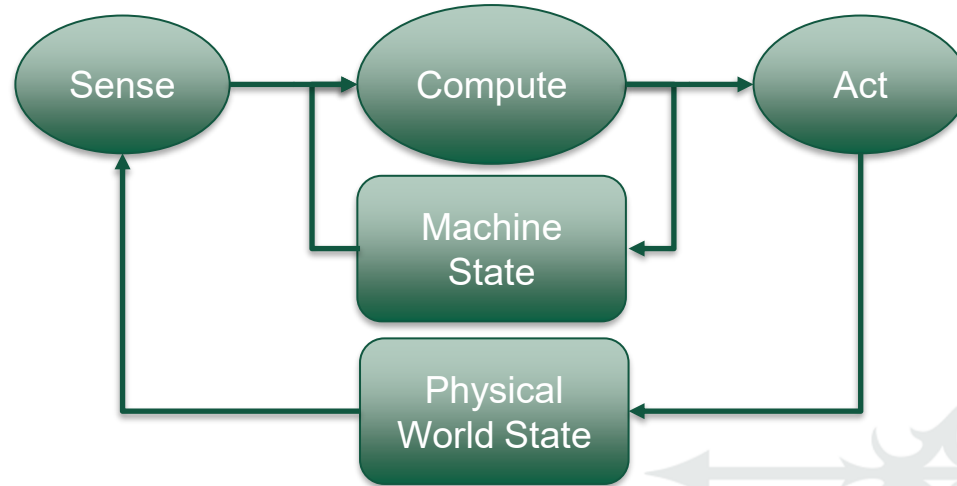
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Robot Arch Design Attributes

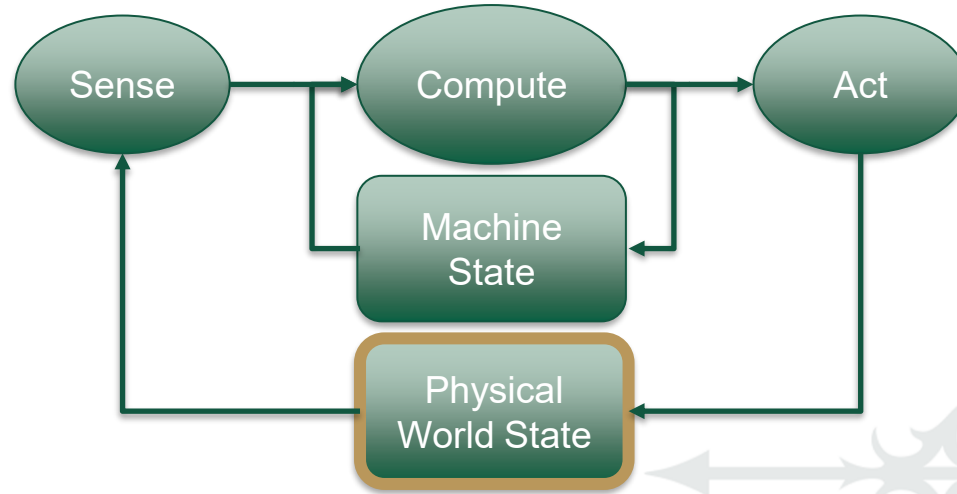
- Asynchronous, Event Driven
 - World operates this way!
- Decoupled
 - Parallelize, reuse
- Abstracted
 - Manage complexity
- Closed Loop
 - Respond to changes from the world



Conceptual Architecture



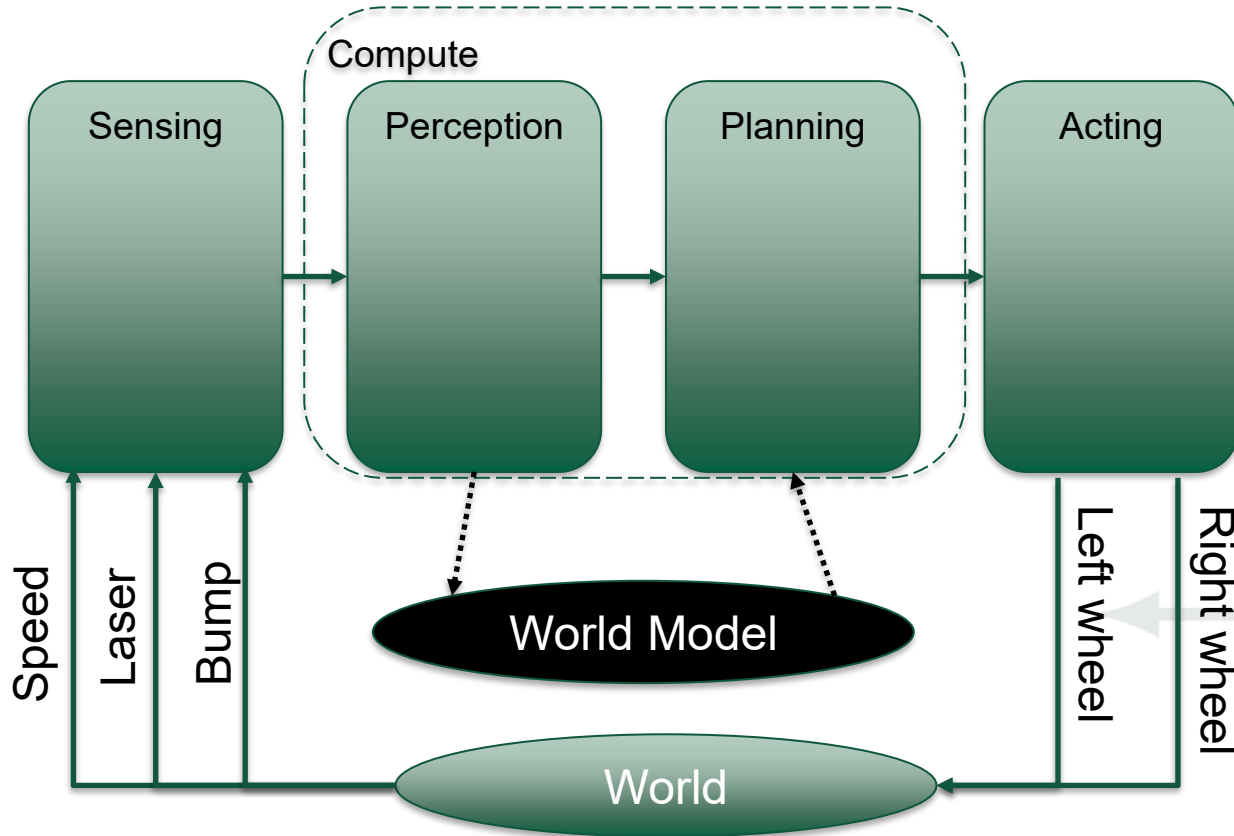
Conceptual Architecture



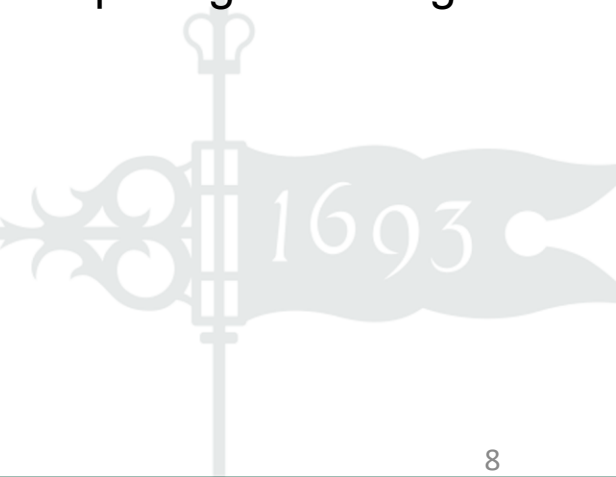
Physical State

- Physical attributes, can change over time
- Some sensed, some estimated
- Robot state examples:
 - Roomba senses velocity, estimates pose
- World state examples:
 - Roomba senses objects, estimates position

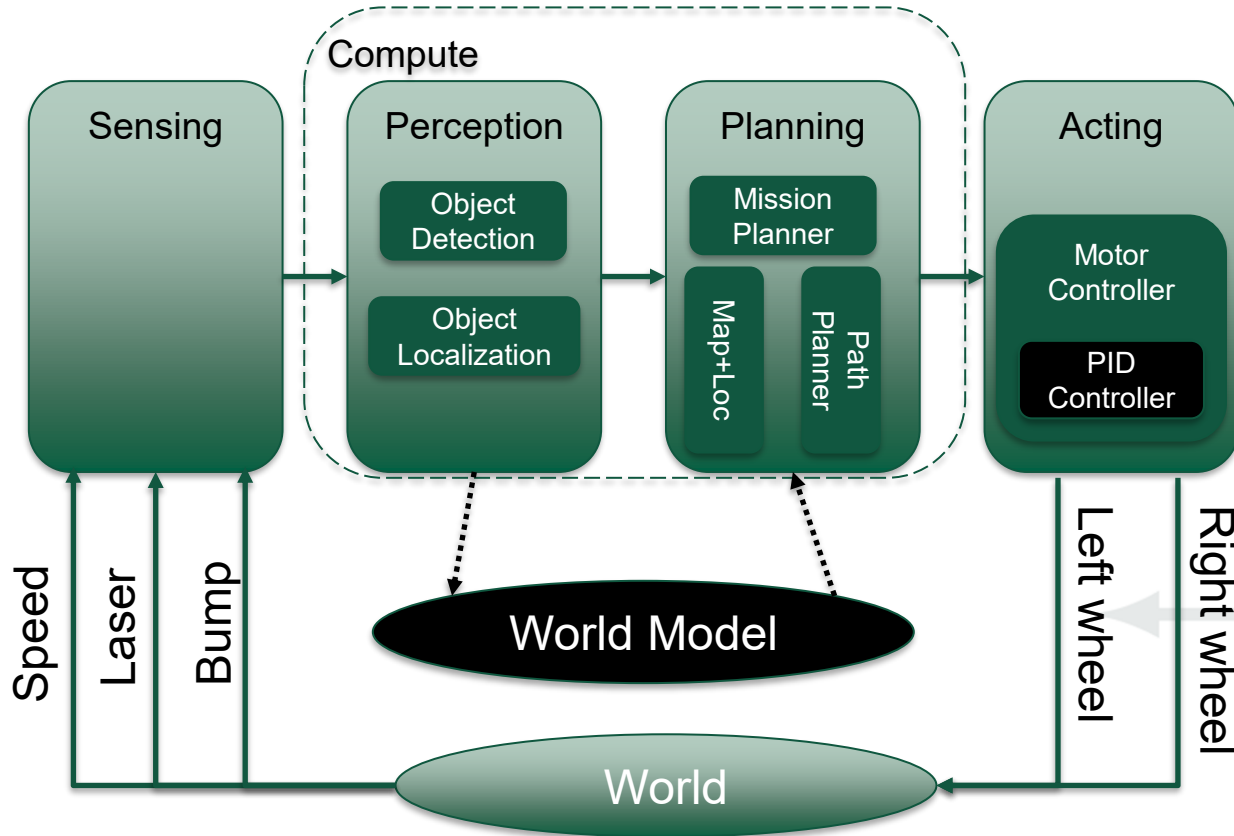
Hierarchical/Deliberative Roomba



Everything managed top-down, one piece at a time, toward completing the final goal



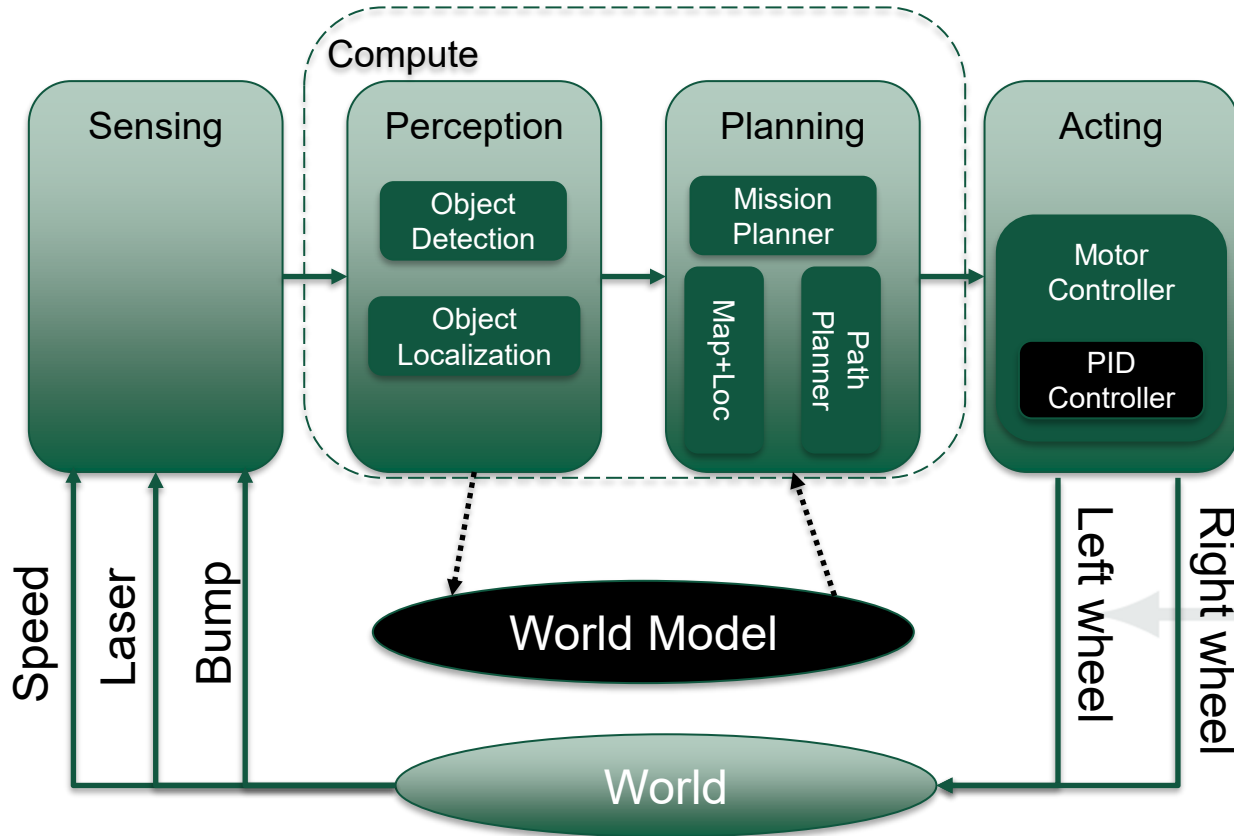
Hierarchical/Deliberative Roomba



As part of top-down, tasks are decomposed for deliberative reasoning

What can go wrong?

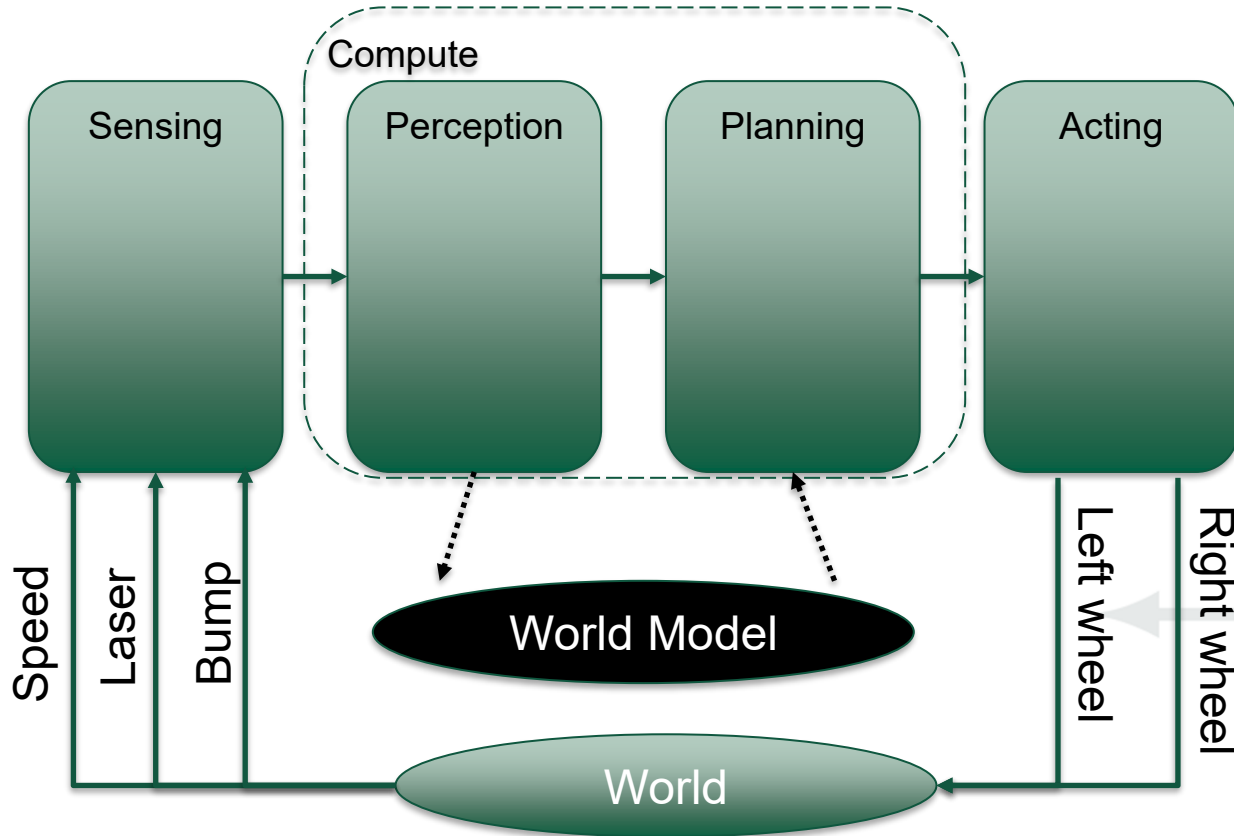
Hierarchical/Deliberative Roomba



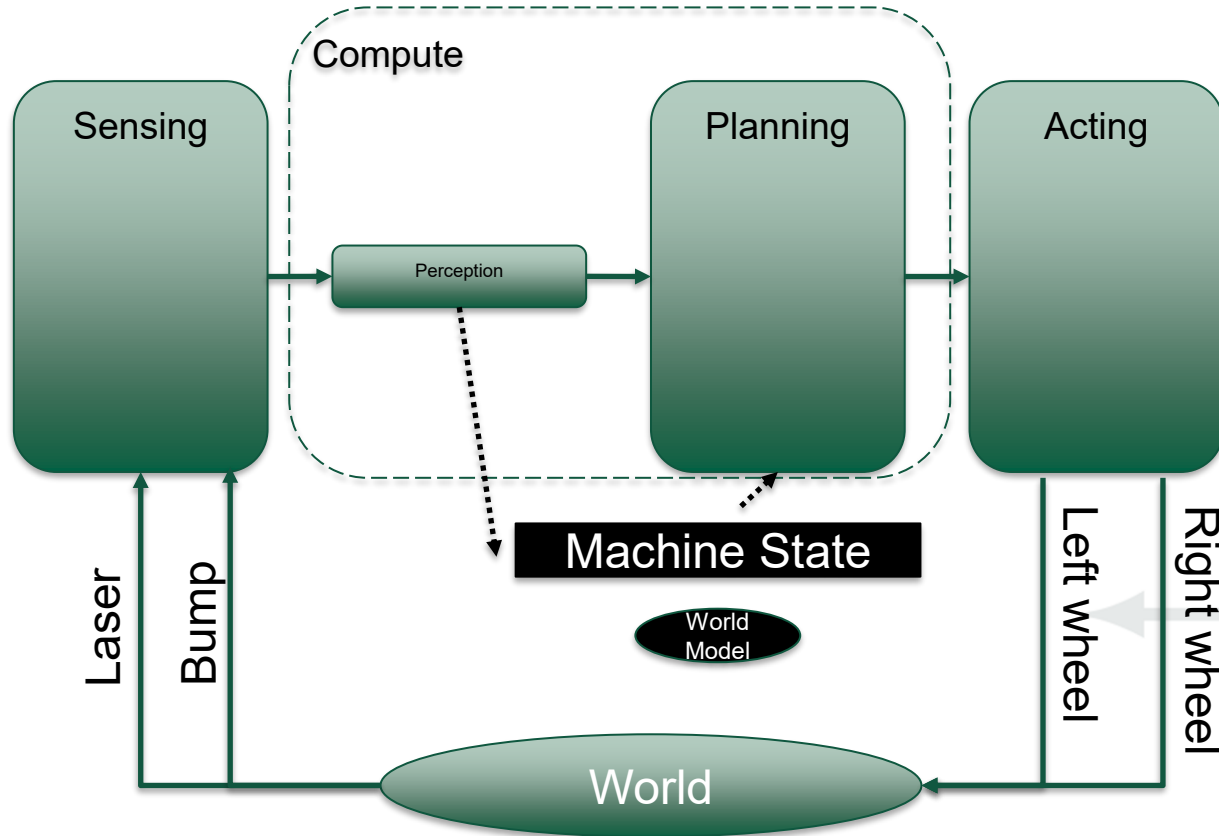
- World too complex to model accurately
- World changes faster than we can plan
- All changes must fit within this modular design

What can go wrong?

Hierarchical/Deliberative Roomba



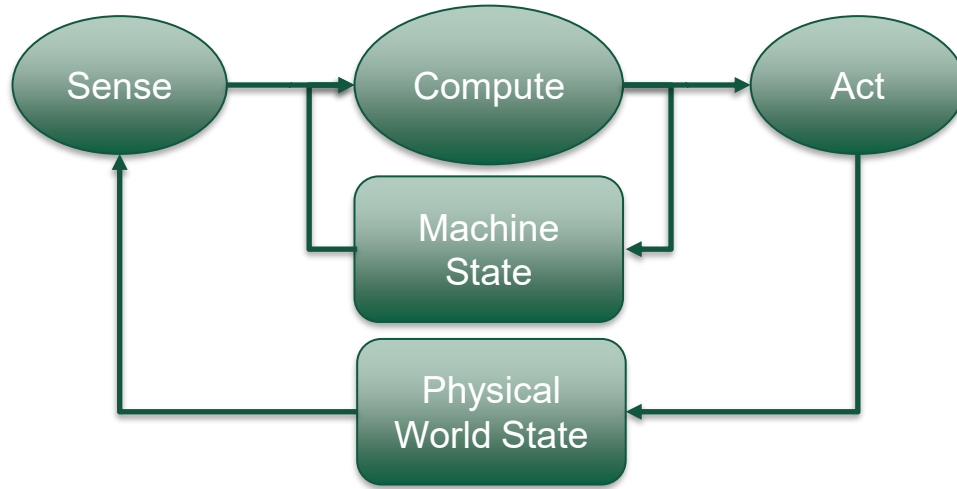
Reactive Roomba



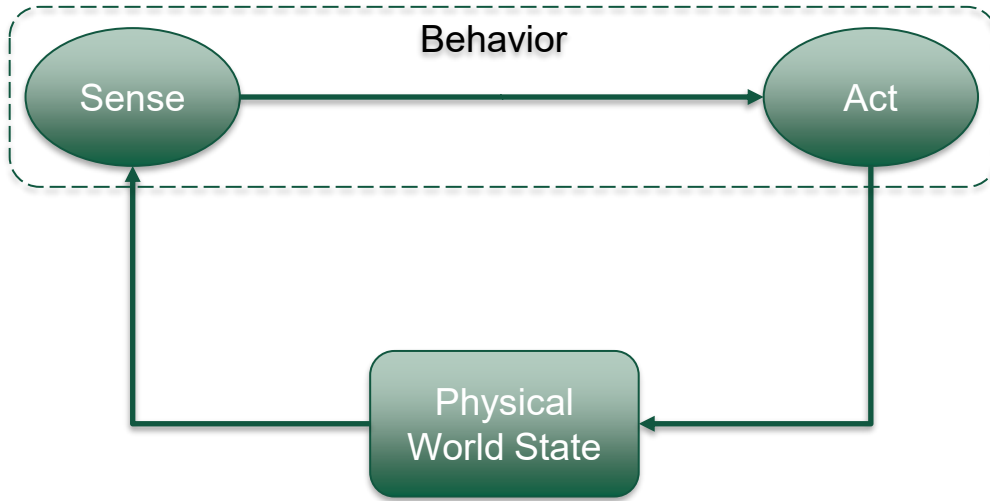
Robot reacts to different senses directly

- Bio-inspired – Insects!
- No/Less reliance on model
- No thinking, just action!

Reactive Robots



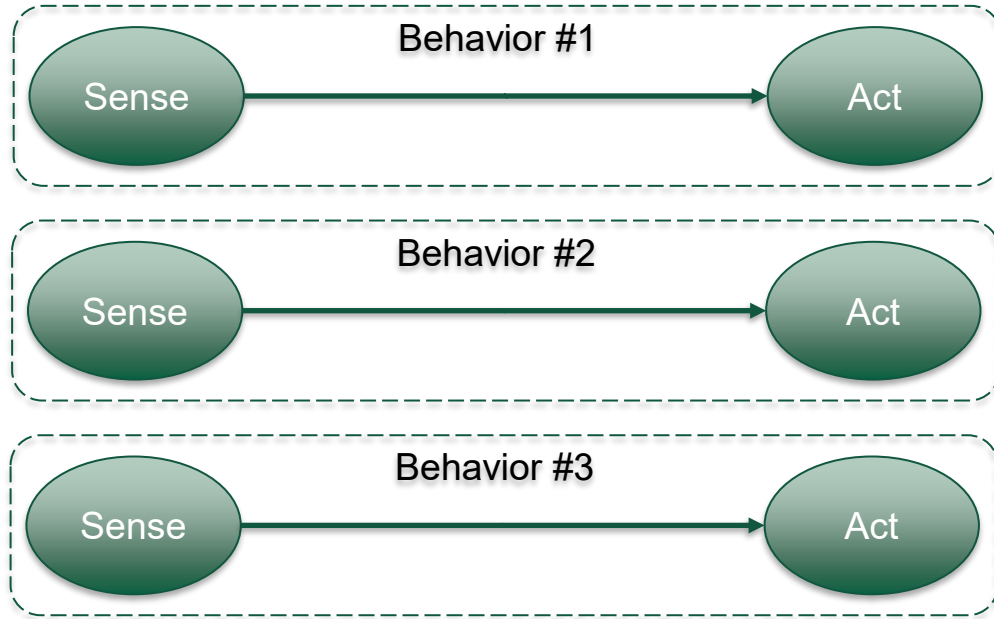
Reactive Robots



Limited compute folded into action



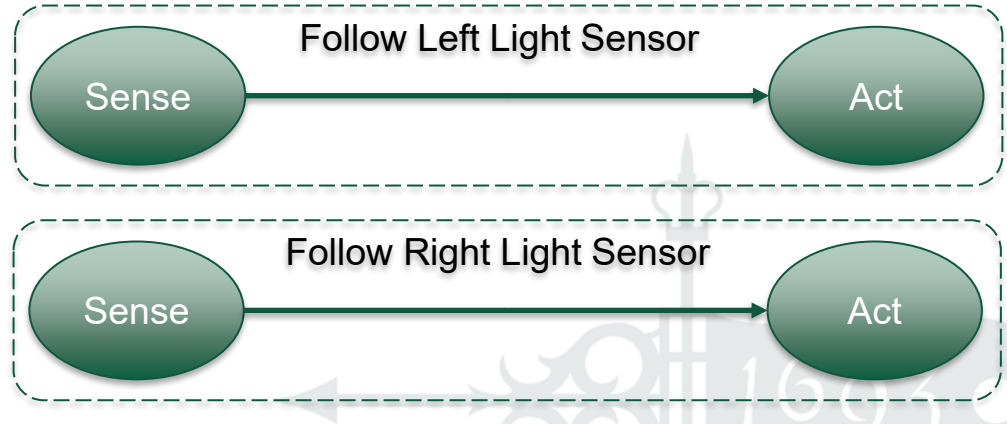
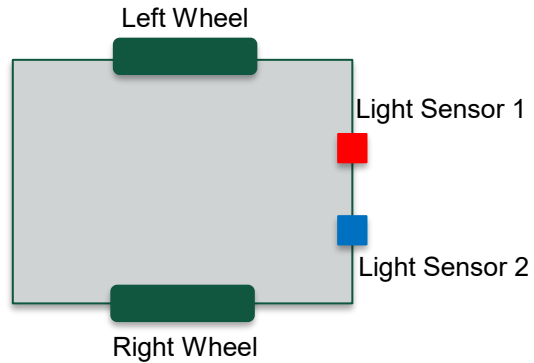
Reactive Robots



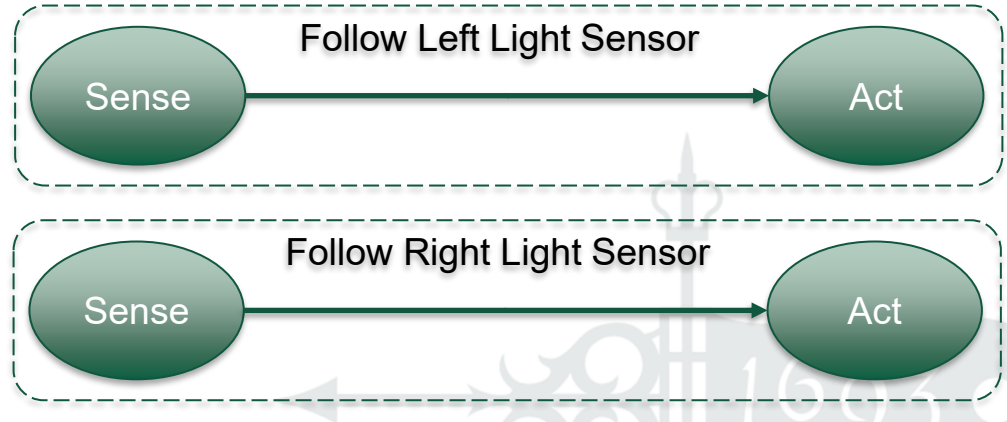
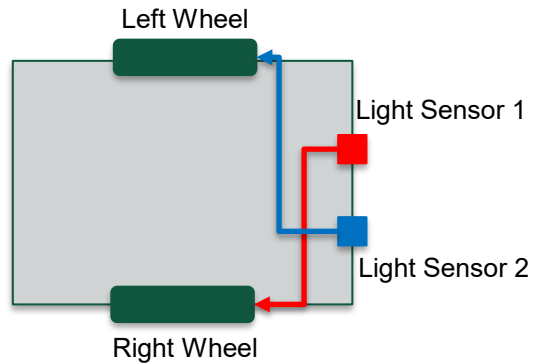
Can decouple separate behaviors



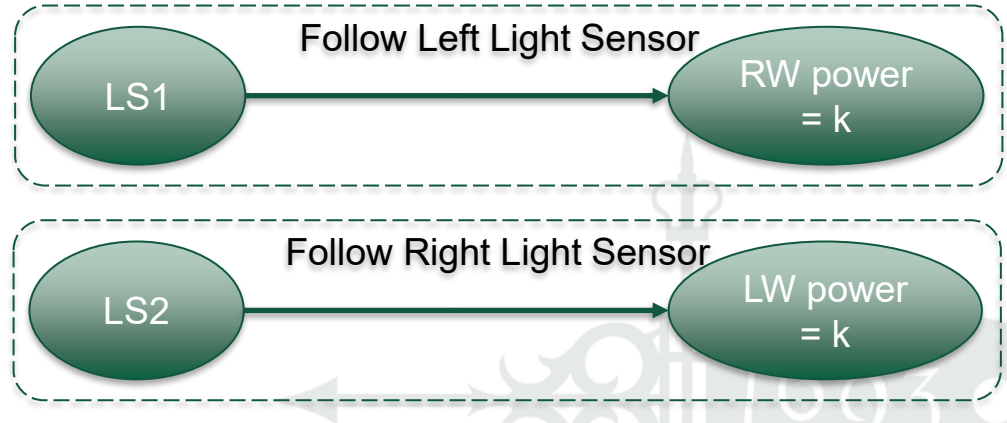
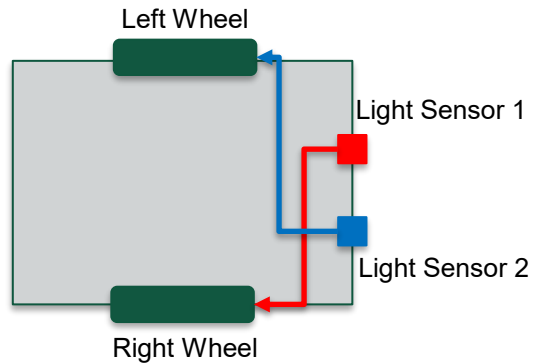
Reactive “Moth”



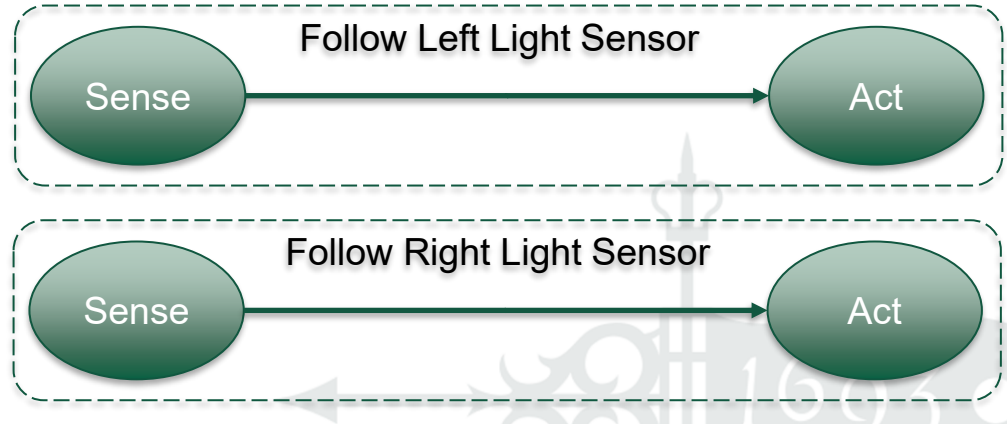
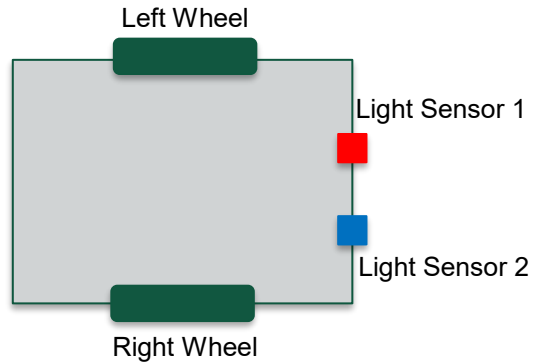
Reactive “Moth”



Reactive “Moth”

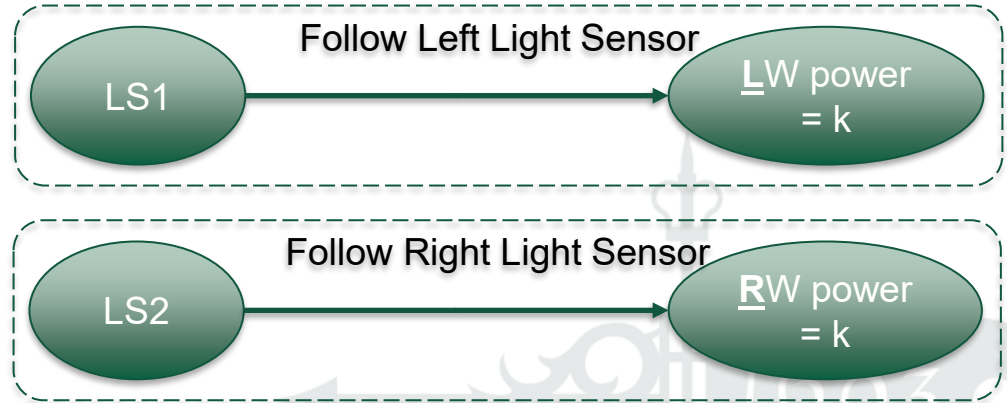
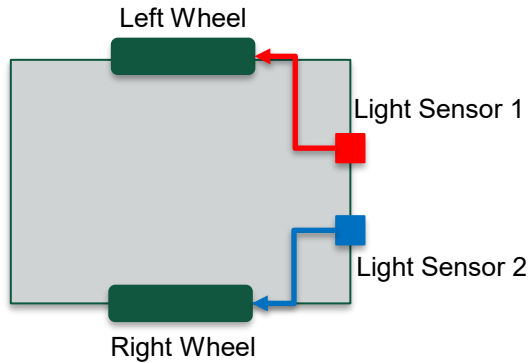


Reactive

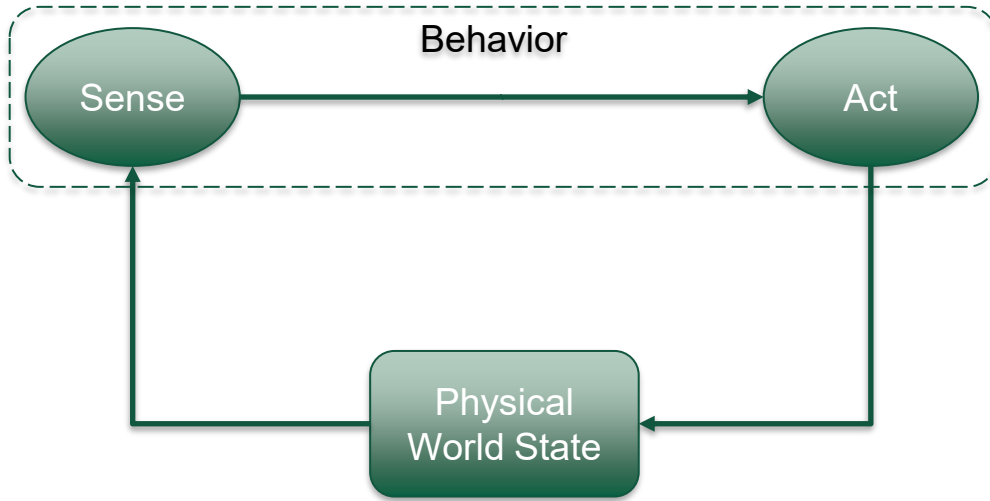


What would a cockroach do
instead to hide from the light?

Reactive “Cockroach”



Reactive Robots

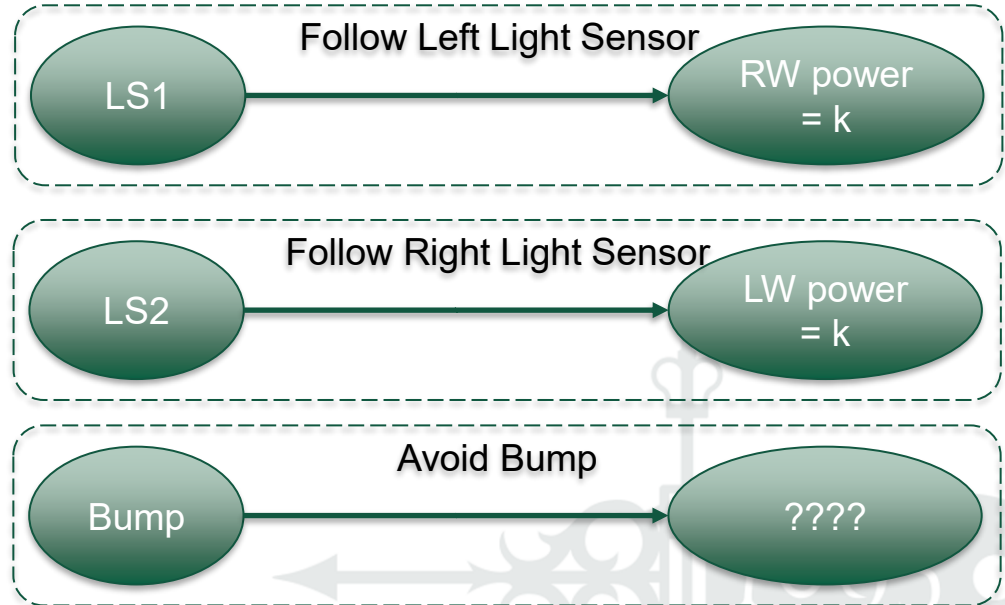
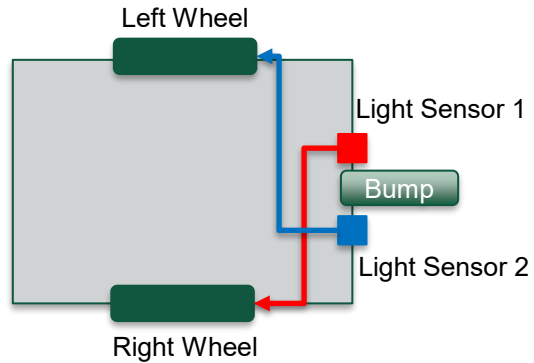


Robot reacts to different senses directly

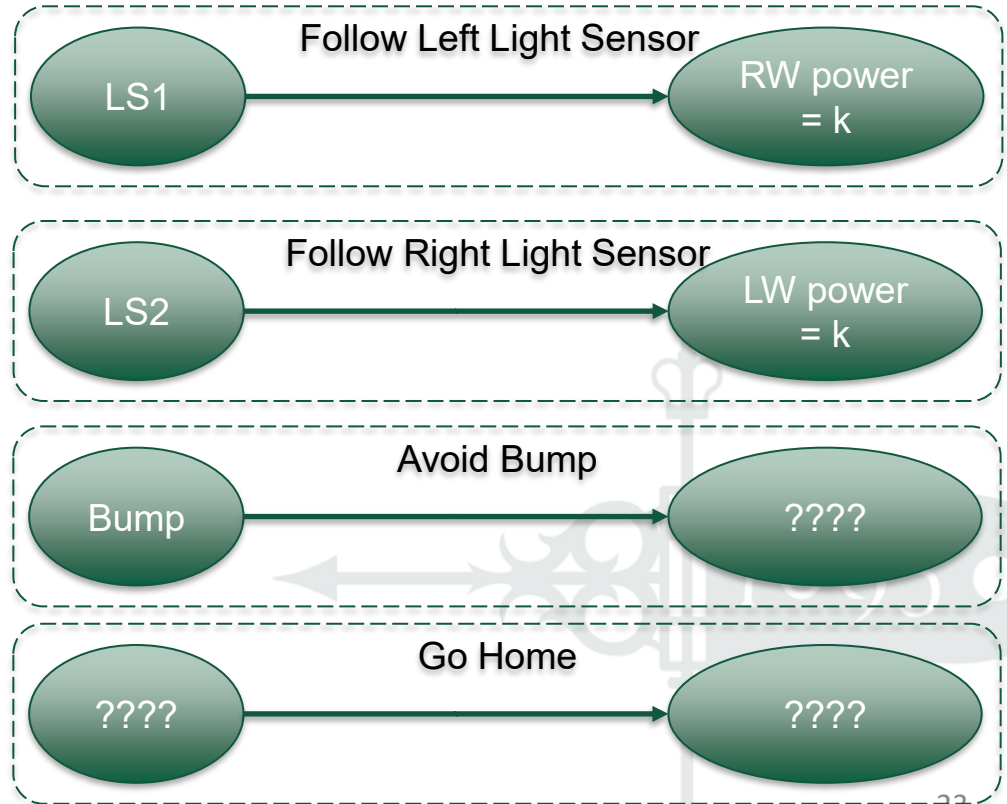
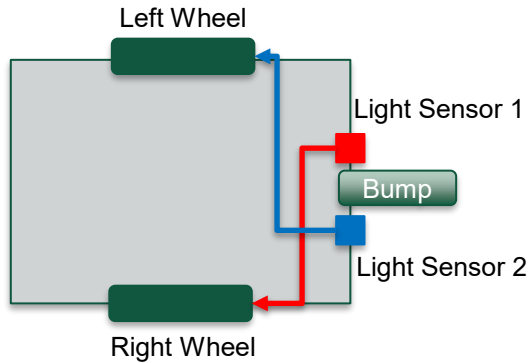
- Bio-inspired – Insects!
- No/Less reliance on model
- No thinking, just action!
- Decomposition of behaviors

What can go wrong?

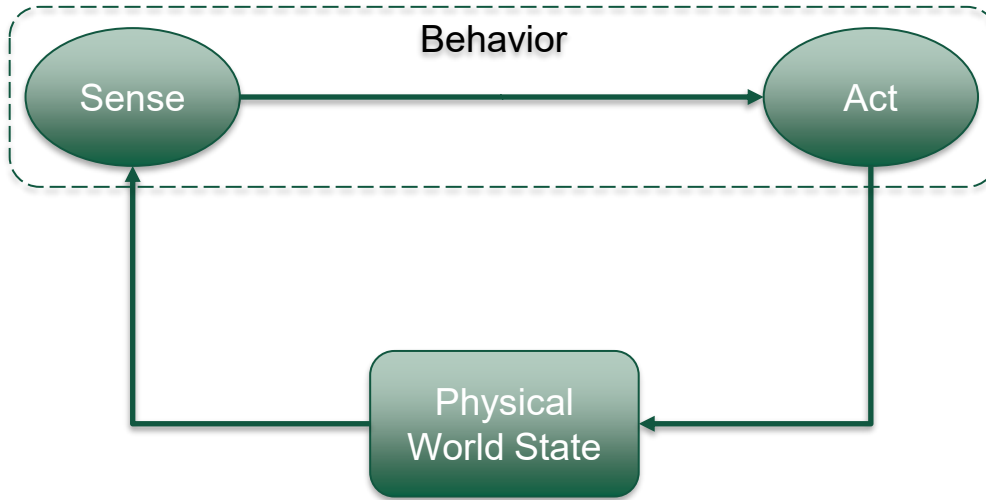
Reactive “Moth”



Reactive “Moth”



Reactive Robots



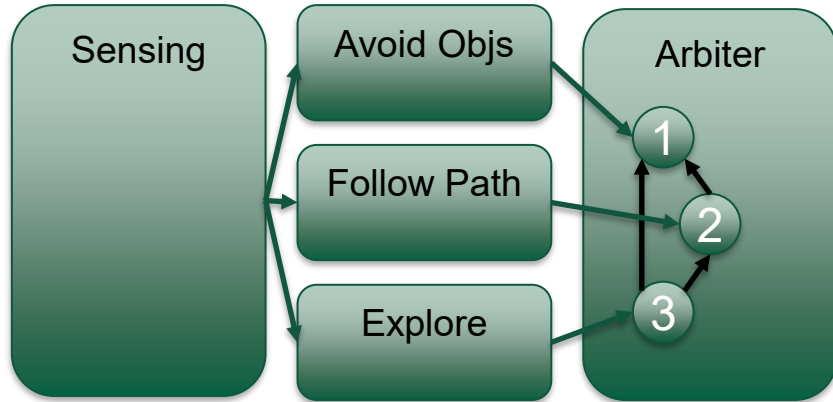
Robot reacts to different senses directly

- Bio-inspired – Insects!
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- Decomposition of behaviors
-

Difficult to:

- Prioritize behaviors
- Handle dependencies
- Achieve complex goals

Reactive Robots

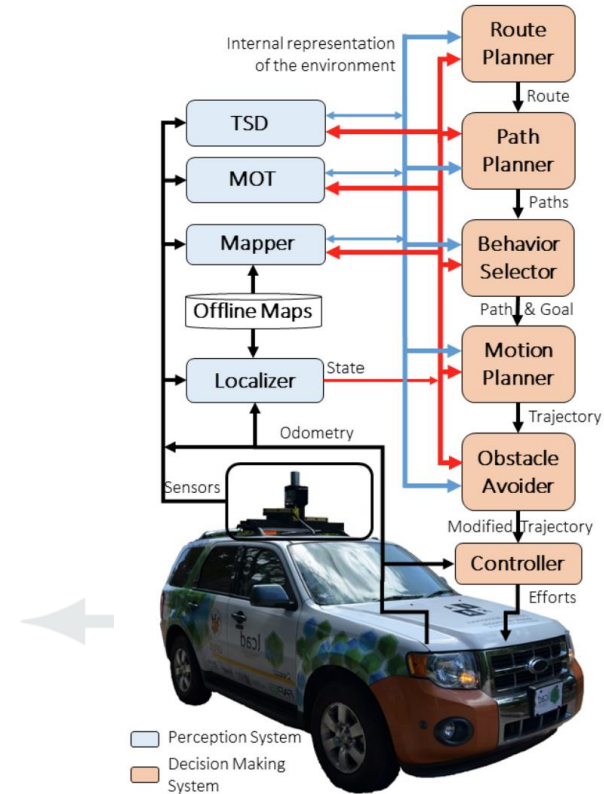


Use an arbiter or additional logic to choose between multiple actions!



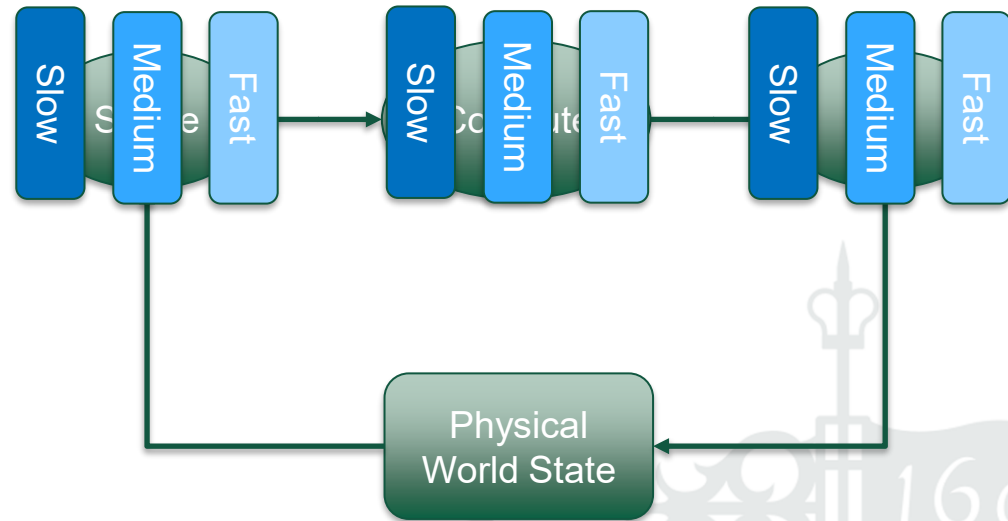
Modular Architecture

- Modular is key!
 - To develop & reuse
 - To test
 - To manage features
- Criteria
 - Features
 - Time



Temporal Decomposition

- Time to
 - Sense
 - Compute
 - Act



Temporal Decomposition

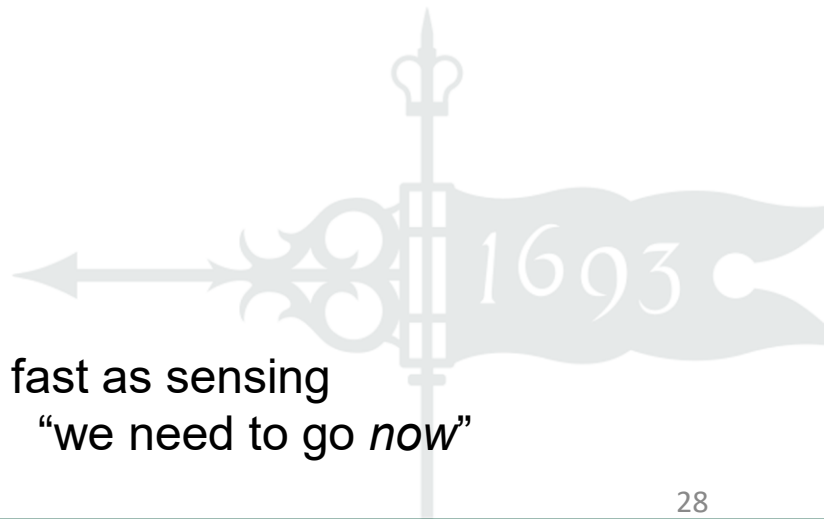
Slow

As slow as deliberative
“as long as it takes”

Medium

Fast

As fast as sensing
“we need to go *now*”



Temporal Decomposition

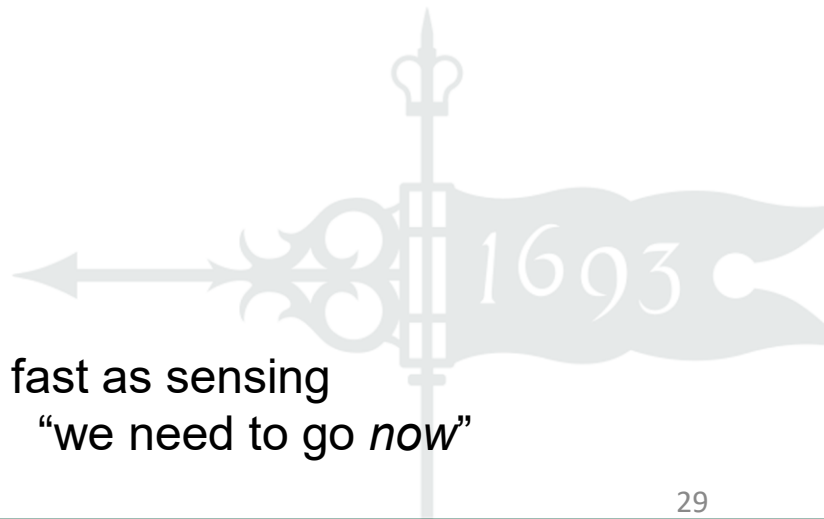
High-level Plan

As slow as deliberative
“as long as it takes”

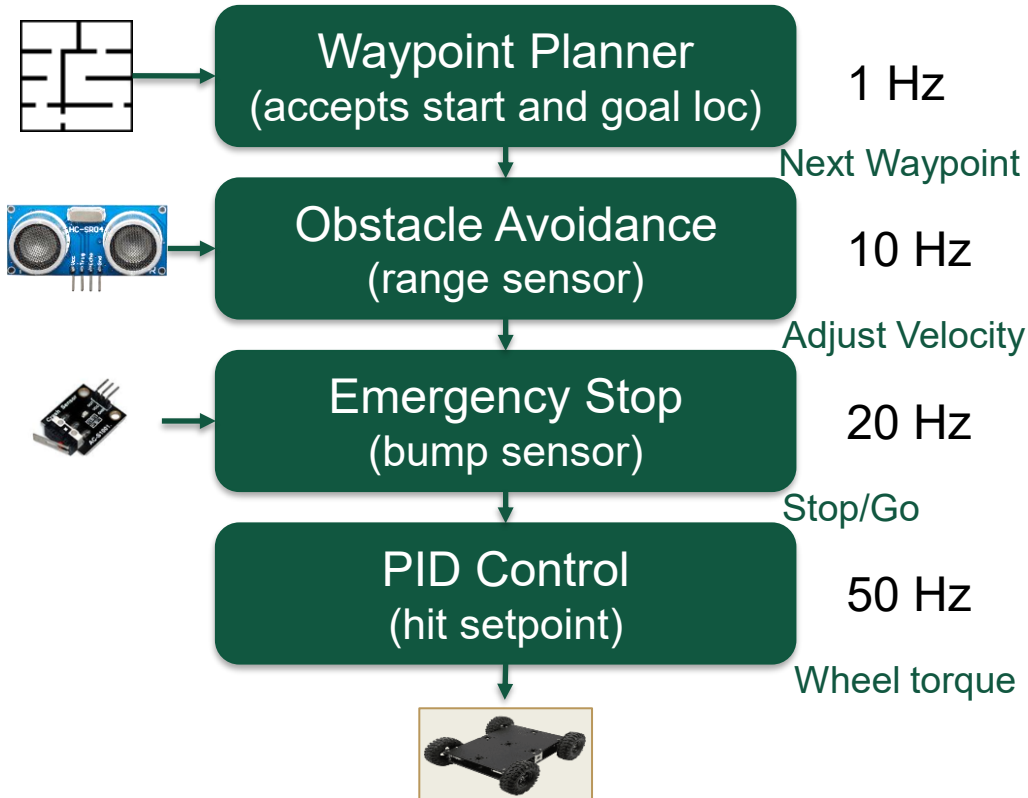
Tactical Plan

Motor Control

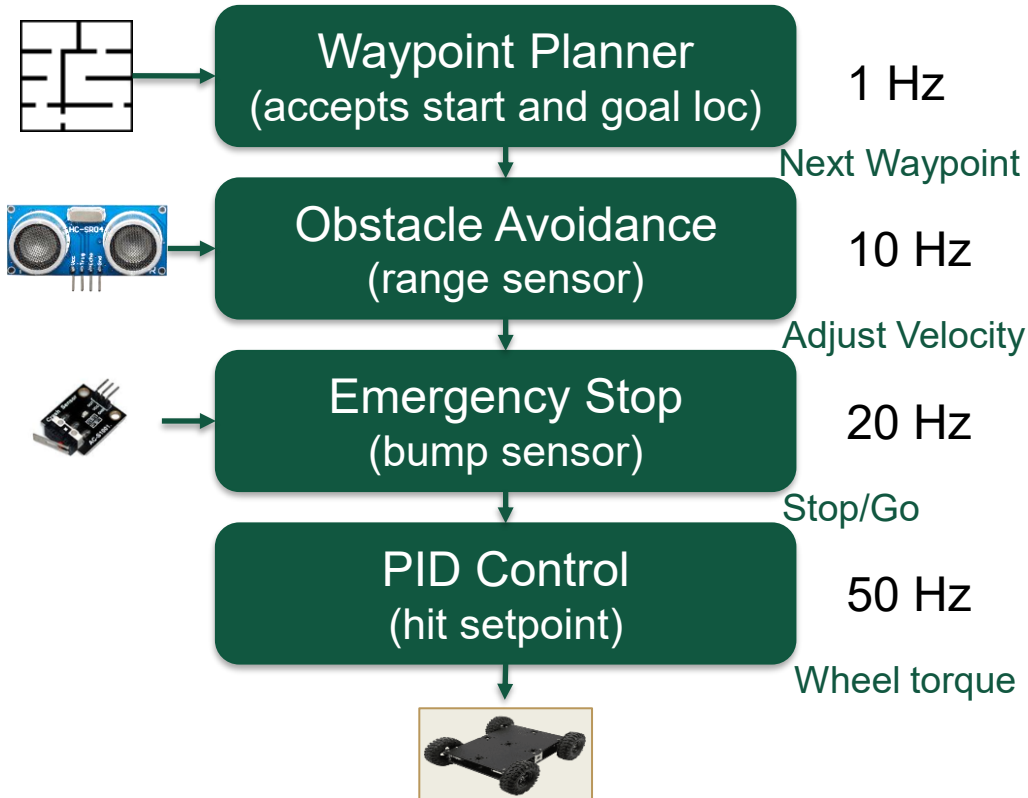
As fast as sensing
“we need to go *now*”



Temporal Decomposition



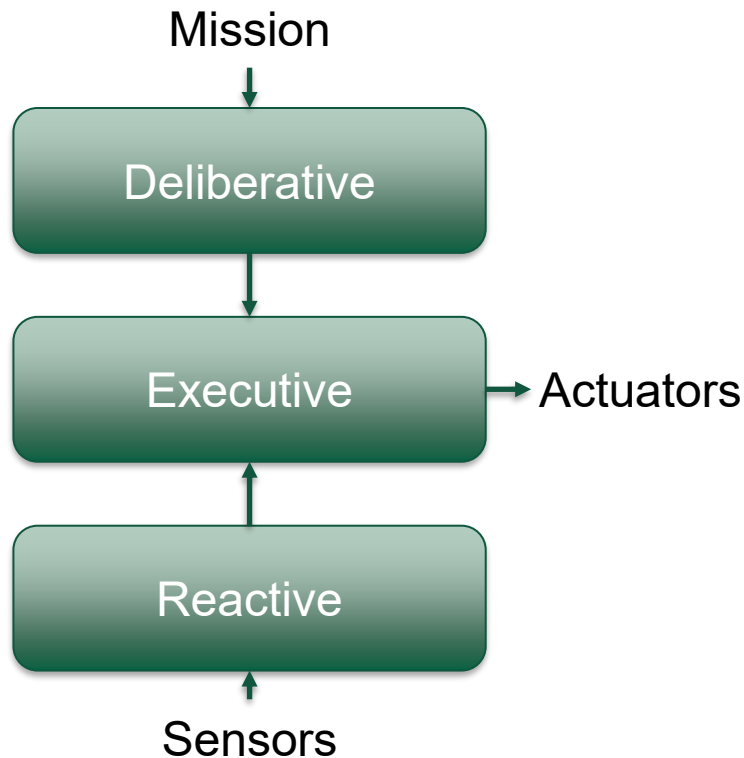
Temporal Decomposition



Decomposition Criteria:

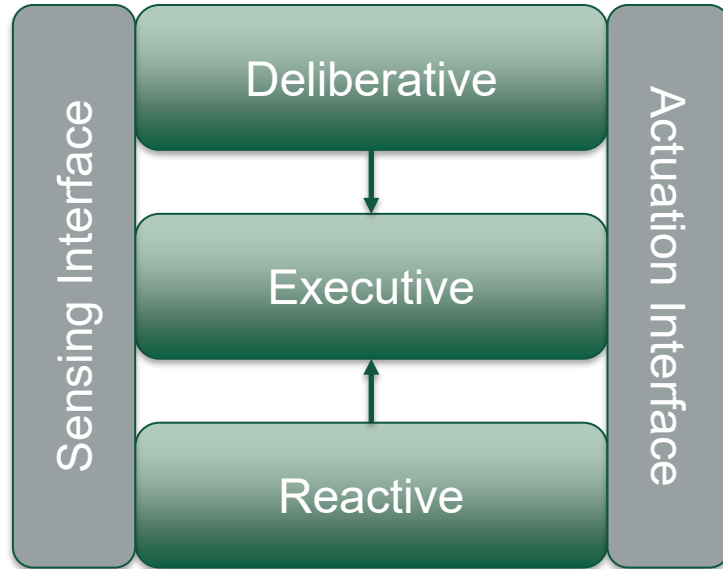
- Model needed
- Memory & lookahead
- Sensor speed

Hybrid Architecture

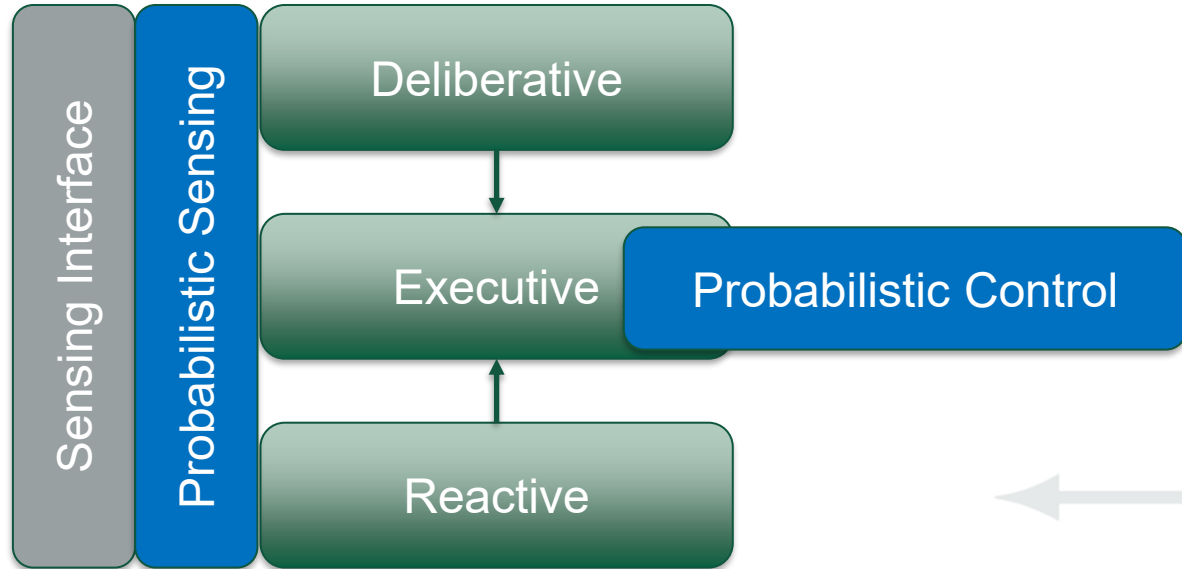


- **Deliberative**
 - Long-term
 - Uses World Repr.
- **Executive**
 - Glue
 - Maintains Repr.
- **Reactive**
 - Low-level Behavior
 - Connects sensors-actors

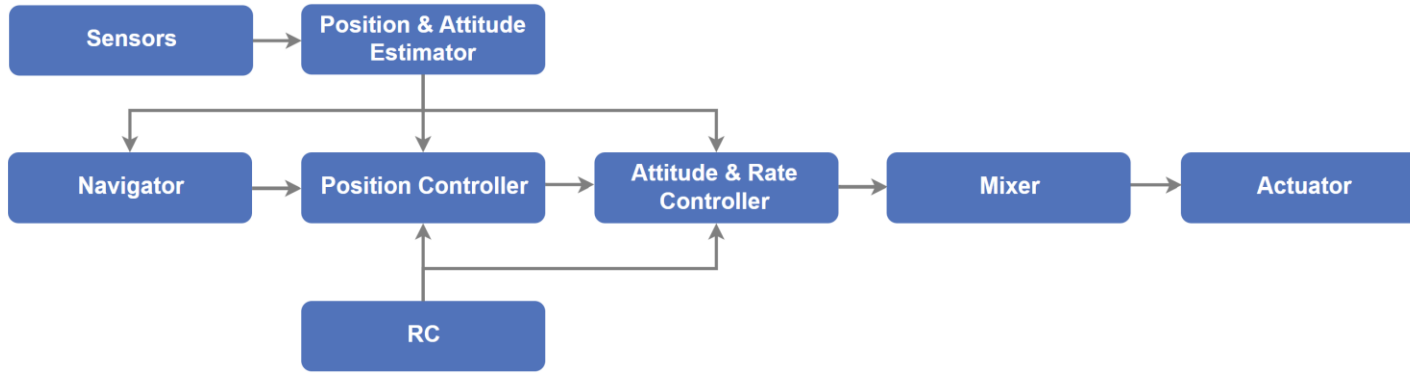
Variations



Variations: Probabilistic

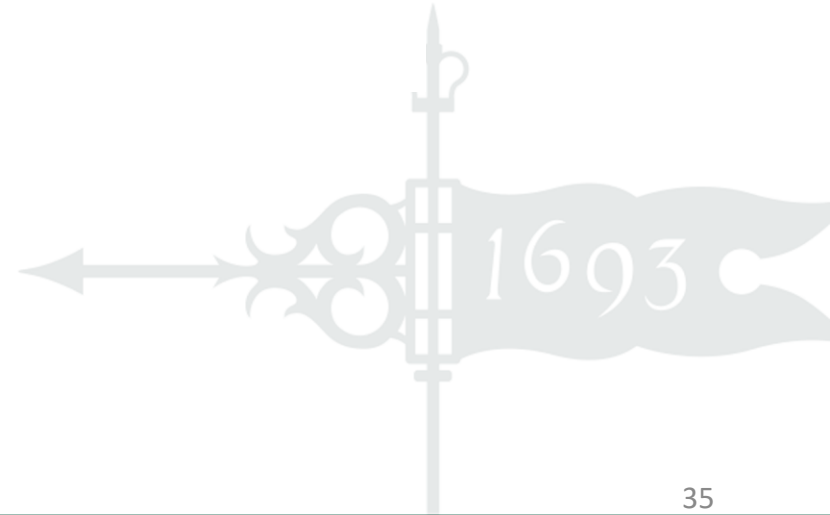


Reality is Complicated

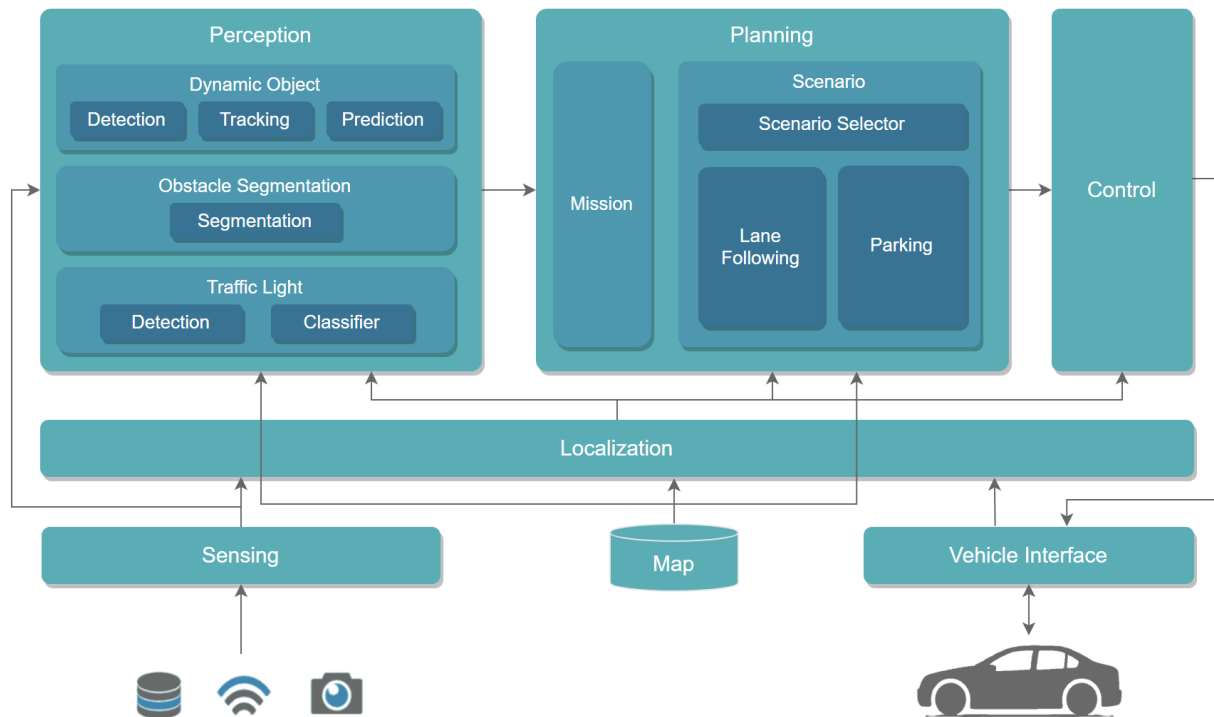


PX4 Drone:

<https://docs.px4.io/main/en/concept/architecture>

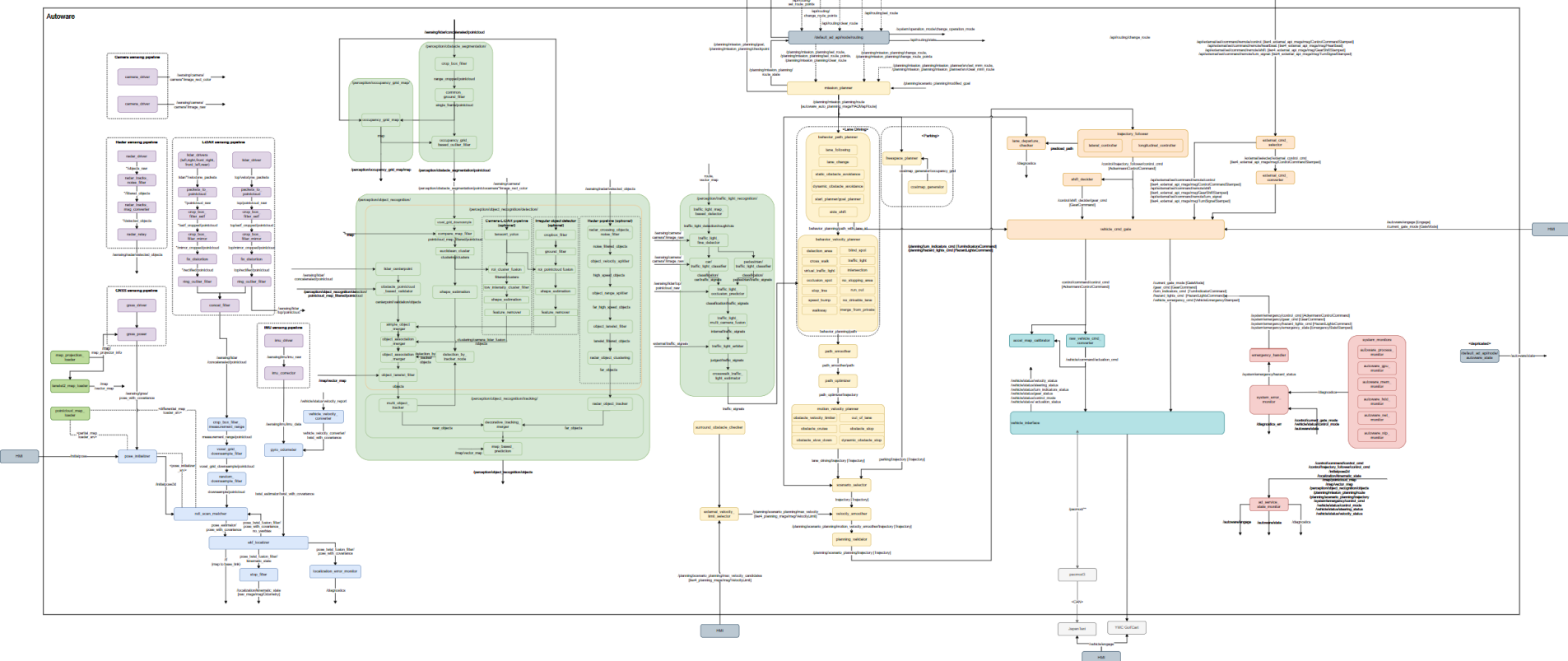


Reality is Complicated



Autware Autonomous Vehicle:

<https://autwarefoundation.github.io/autware-documentation/main/design/autware-architecture/>



Robot Architectures

- Deliberative
 - Think hard, act slow
 - Use world model, look ahead, stateful
- Reactive
 - No thinking, only reacting
 - Fast, no models, only behaviors
- Hybrid
 - Think and act independently
 - Combine short-term and long-term

