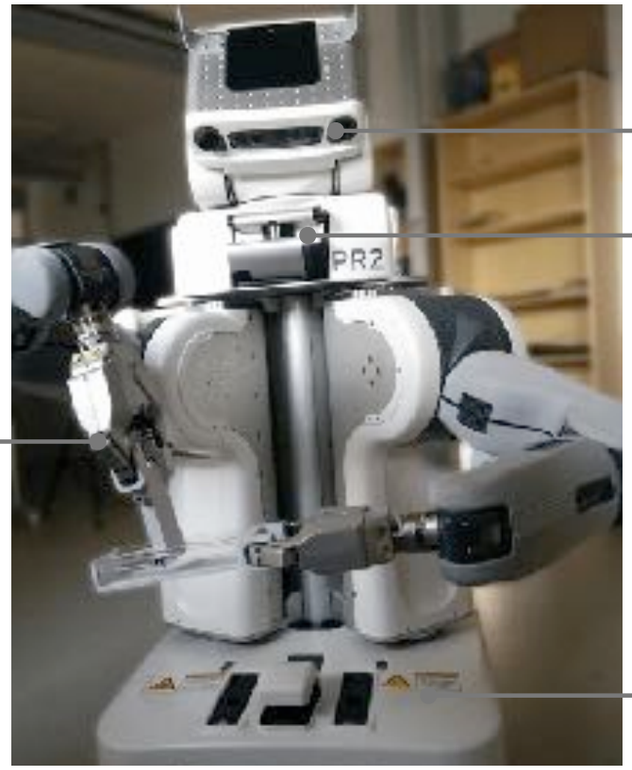
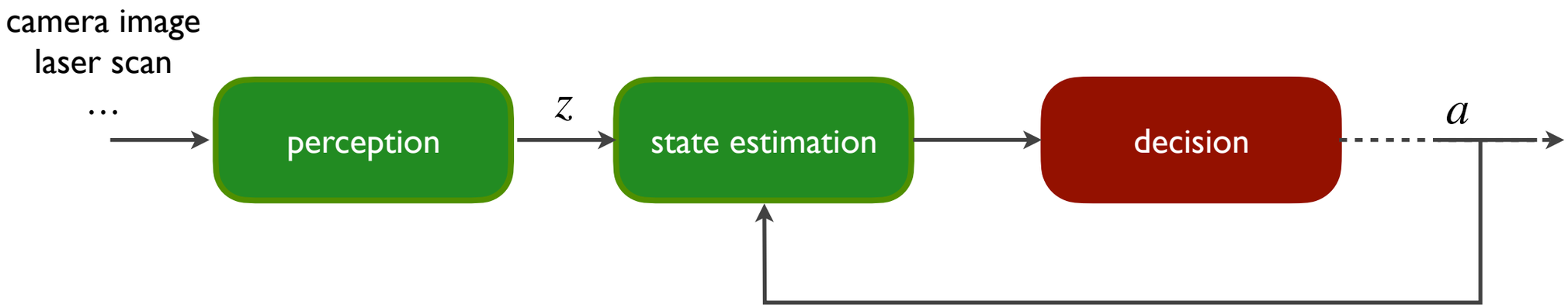
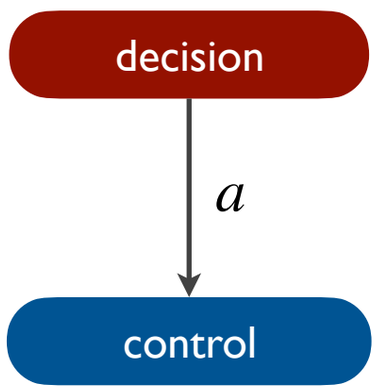
What is a robot system made of?

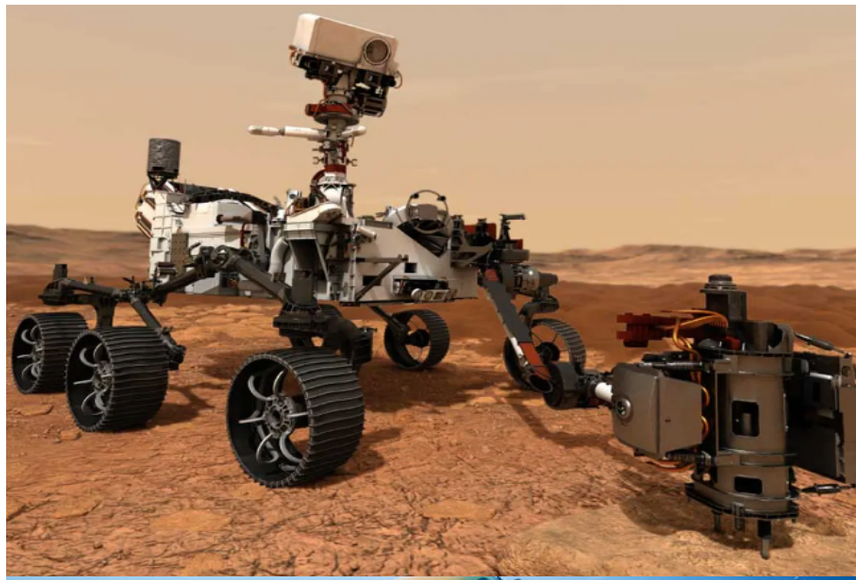


Last lectures ...






BostonDynamics




PACKSE

Robot architectures. We learned to construct powerful components for robot perception, state estimation, decision, control, … Following the **modular system design** approach, we design, implement, and test each module and integrate them.

There are many architectures for integration. An illustrative example of the most common architecture is shown below:

…

This example architecture consists of two hierarchical layers. The upper layer performs global reasoning, e.g., finding a route from NUS to Changi airport. It runs at a relatively low frequency. The lower layer performs local control, e.g., accelerating to 70 km/h. It runs at a high frequency.

✓ • By decomposing a system into functional components and layers, we can build complex systems incrementally and systematically.

✓ • We can add layers and components when necessary.

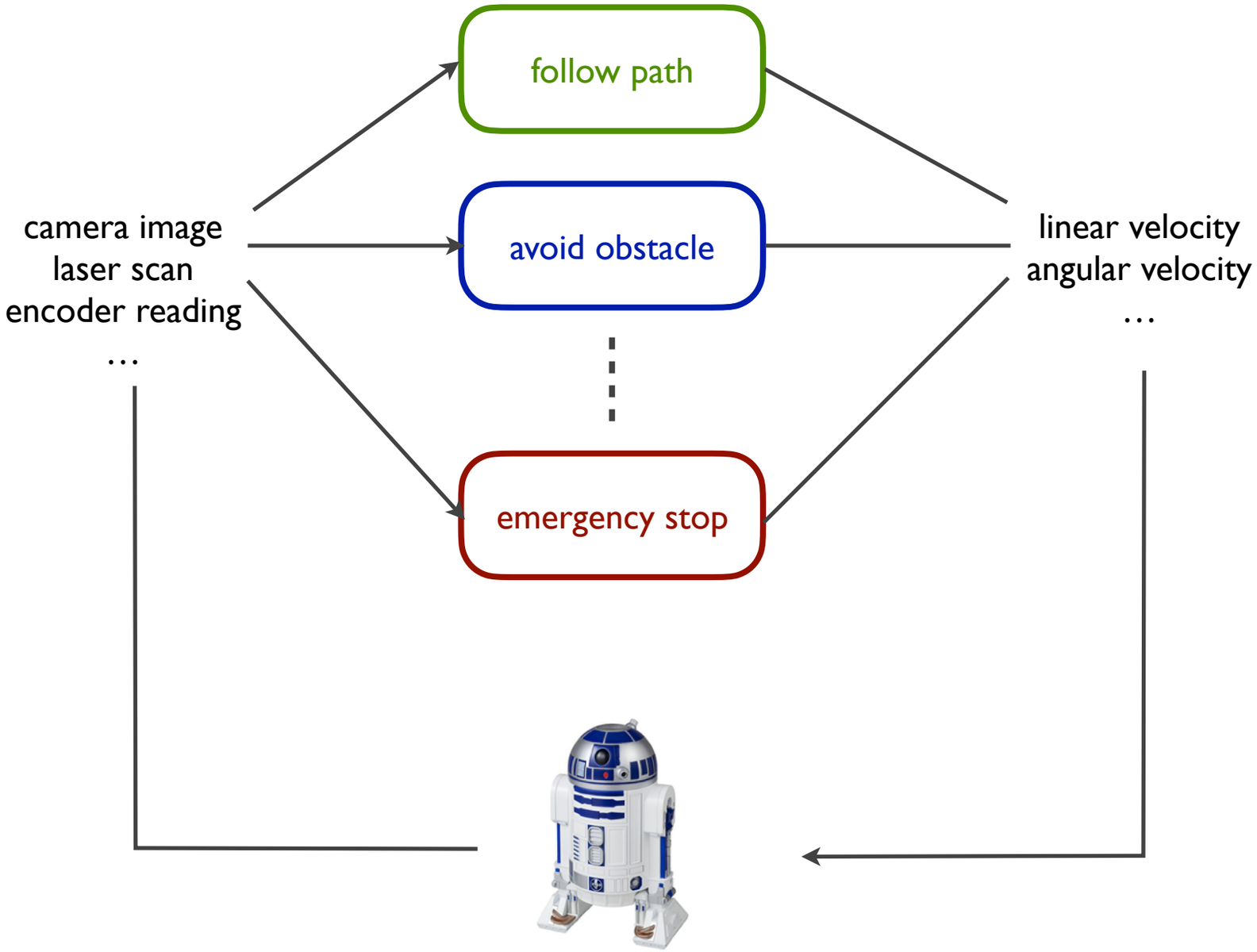
✓ • Each component can be developed independently.

✓ • Each component serves a clearly-defined, well-understood purpose. This eases the difficulty of development and tests.

✗ • For most components, we need **models** of the world:, e.g., robot dynamics, environment geometry, sensor noise, … Acquiring accurate world models is often challenging and requires domain expertise and creative thinking, in other words, the design engineer's brain.

Instead of building models, we can build behaviors, roughly, policies. The subsumption architecture consists of a set of interacting **behaviors**.

- All behaviors coexist and act simultaneously. One behavior may inhibit or suppress others. For example, if the robot performs an emergency stop, it cannot follow a path at the same time.
- Behaviors can be structured hierarchically: a behavior may invoke sub-behaviors.



The subsumption architecture is also modular and offers the usual benefits of a modular system. At the same time, it has some unique characteristics.

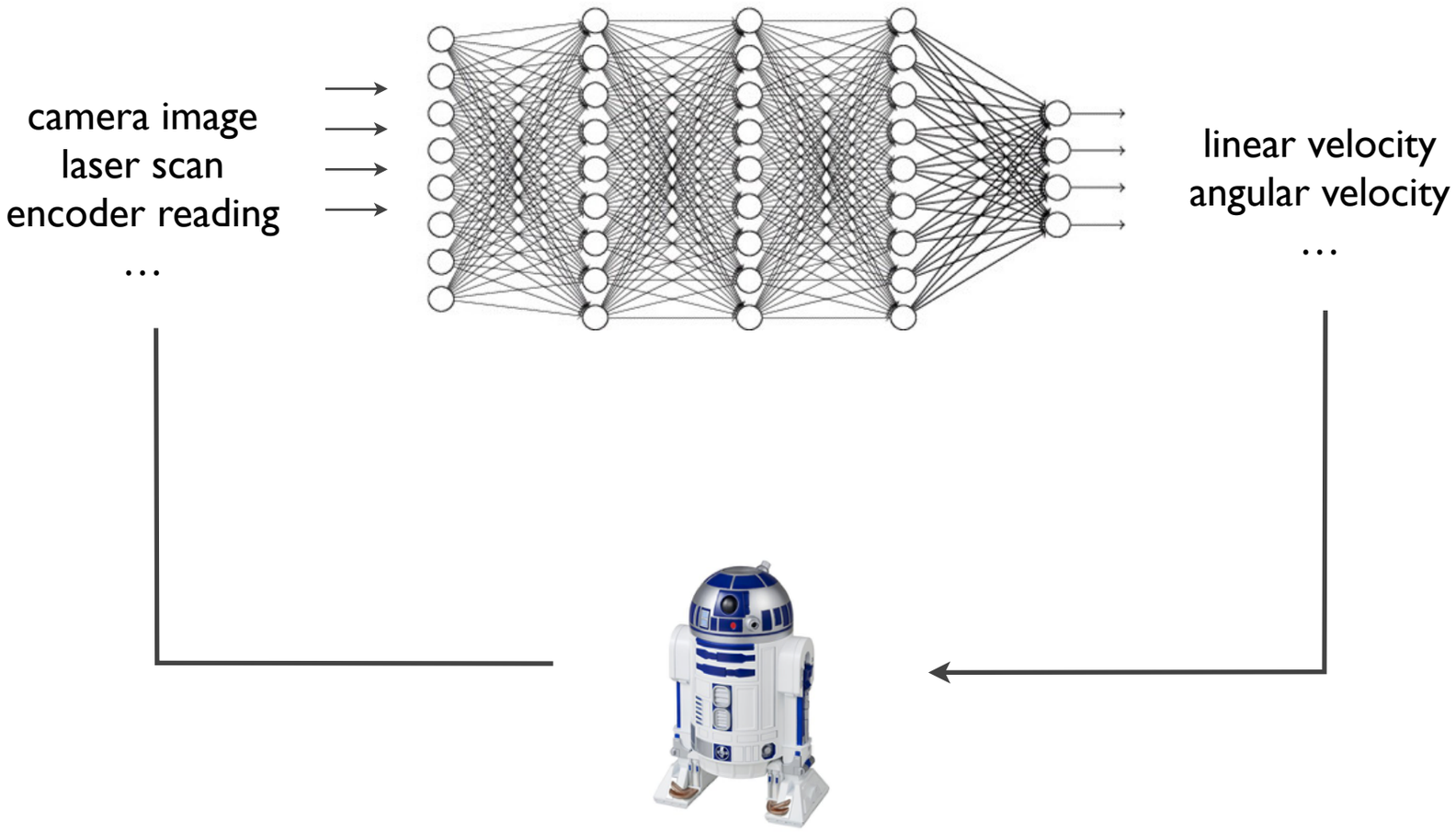
✓ • As all behaviors act in parallel, the overall system response is fast. In fact, the subsumption architecture is designed for real-time performance.

✗ • Unfortunately, acquiring complex behaviors are even more difficult than acquiring complex models.

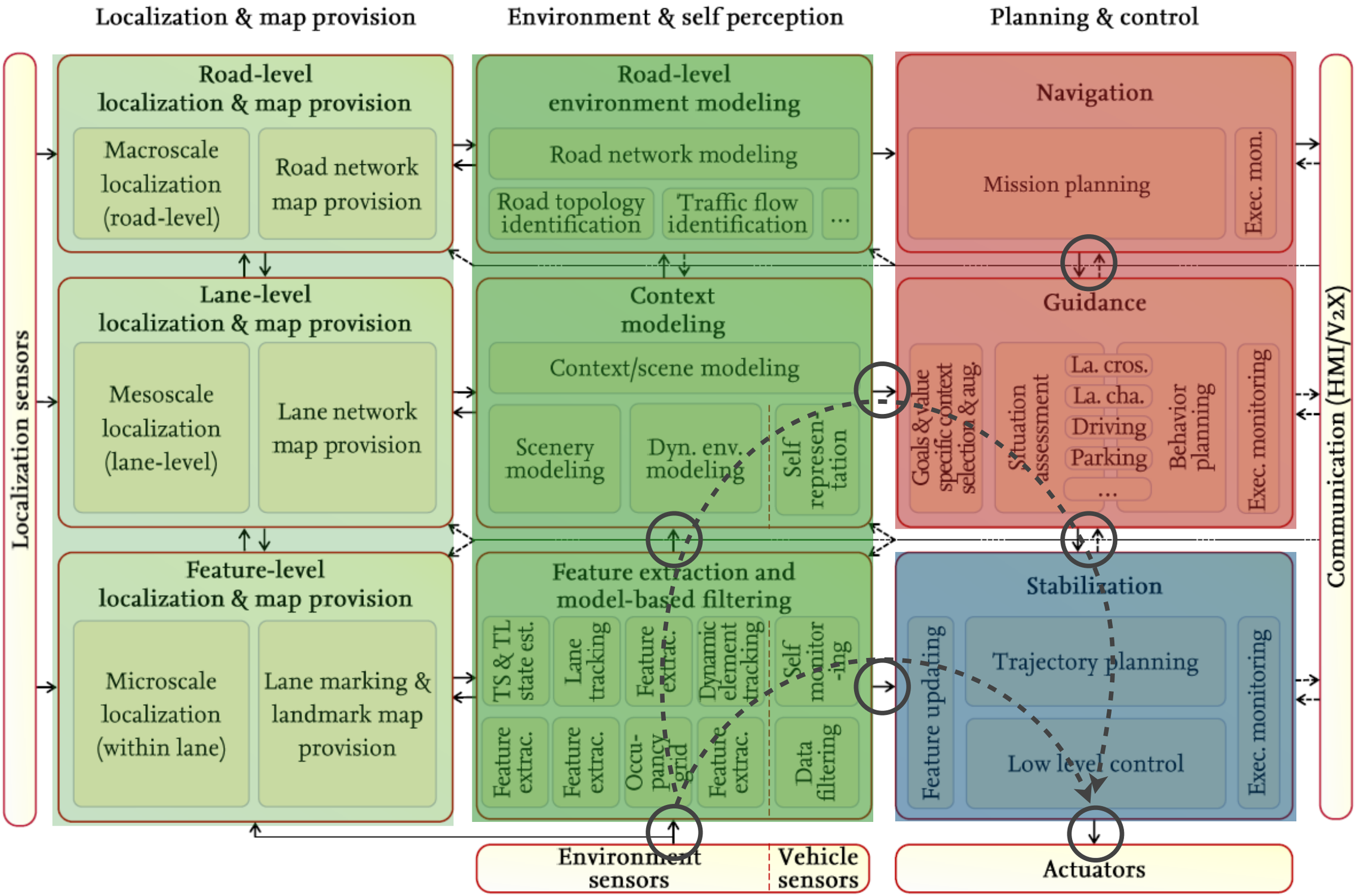
✗ • As more and more behaviors are added, they interact in complex ways that are difficult to anticipate and control.

The subsumption architecture was important historically, but no longer widely practiced in its entirety. Its influence, however, exists in many robot architectures, in various forms.

The rise of deep learning has brought about the end-to-end (e2e) learning system. It replaces all system components by a single giant neural network.



An autonomous driving system.



Summary.

- There are many considerations in choosing a robot architectures:
  - Modularity and scalability
  - Robustness
  - Real-time response
- The technical merits between model-based modular systems and data-driven e2e learning system are hotly debated. They are, however, not mutually exclusive. Integrating model-based and data-driven approaches likely lead to the best performance.

Required readings.

- [Siegwart, Nourbakhsh & Scaramuzza] Sect 6.5

Supplementary readings.

Key concepts.

- Model-based modular system
- End-to-end learning system