Robot Architectures

- Organizing a robot (software) control system.

BLG456E
Robotics
Robot Software Architectures

- Temporal Decomposition
- Main Architecture Types
  - Deliberative.
    - Planning Intro
  - Reactive.
  - Behaviour-based.
  - Hybrid.
    - Shakey Example.

Lecturer:	Damien Jade Duff
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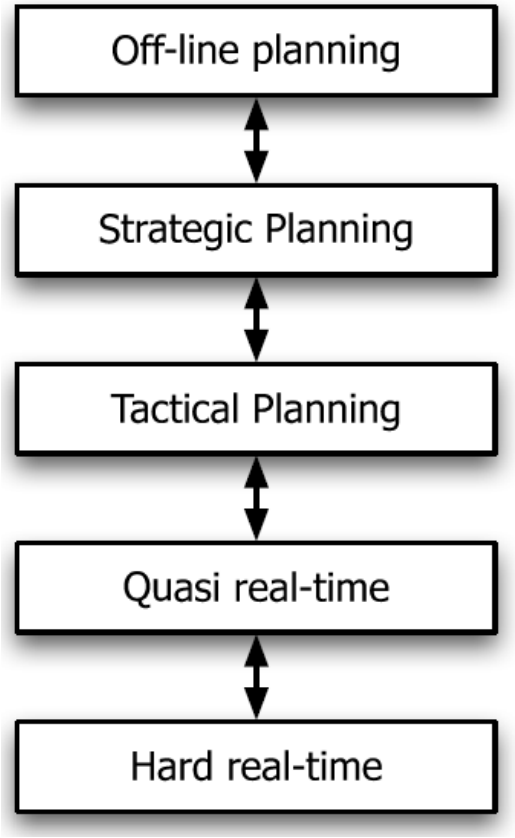
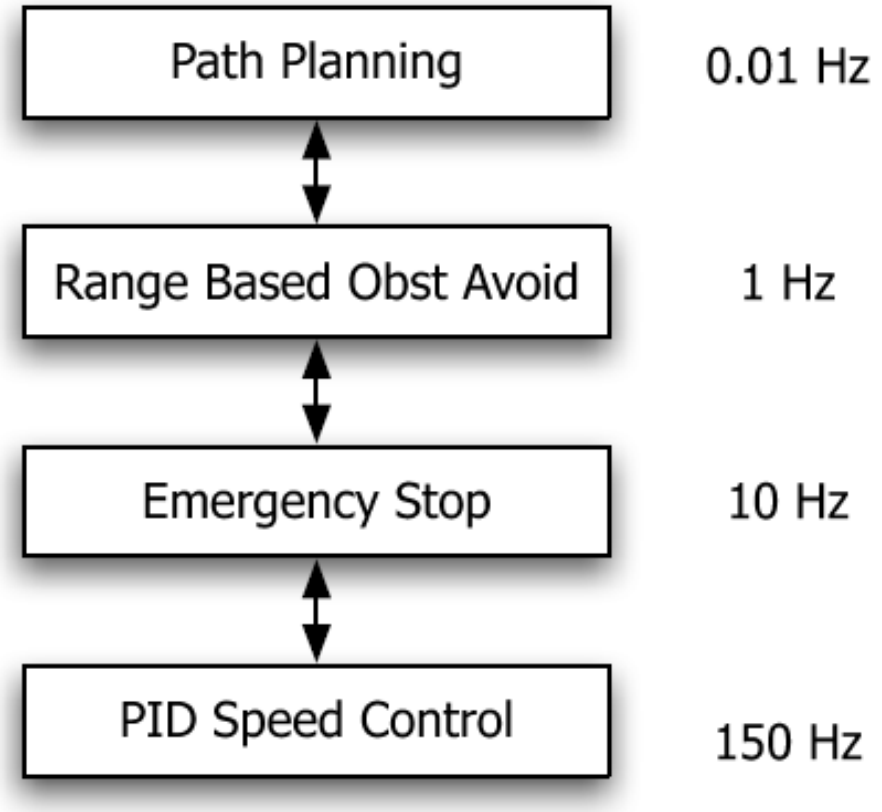
Considerably adapted from work by Dr. Sanem Sarıel-Talay

Temporal decomposition of robot architectures

- Coarse division of control
- Layering can be loosely synchronous



Sample Mobile Platform Decomposition



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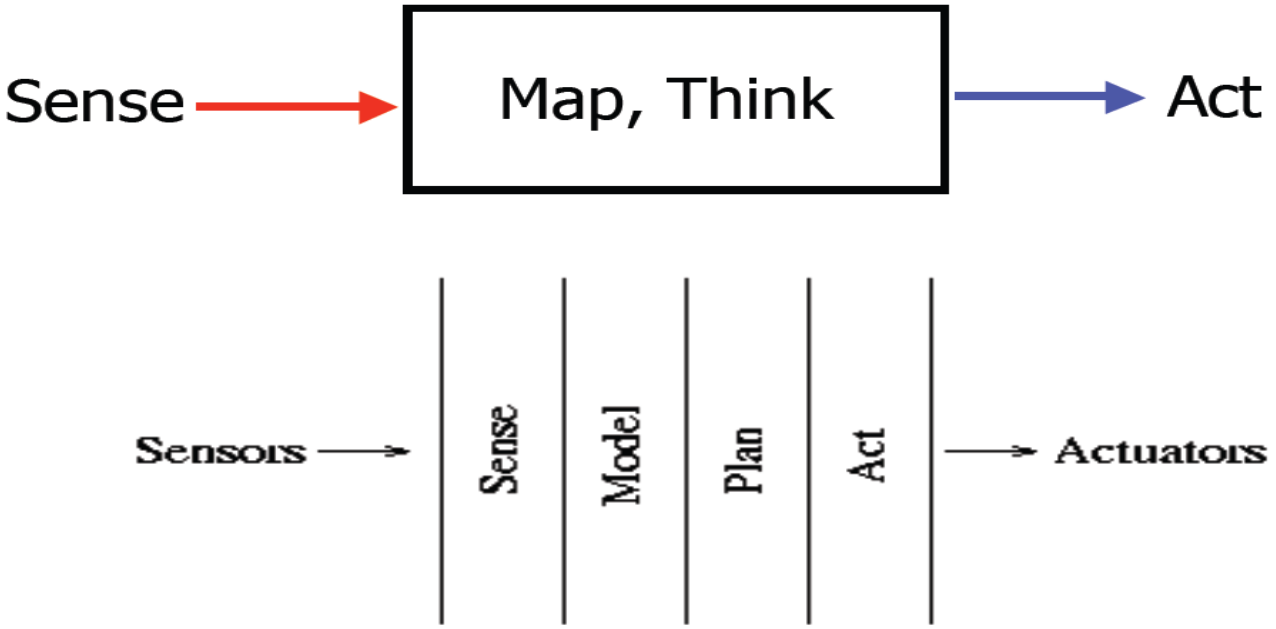
Control Architecture Types

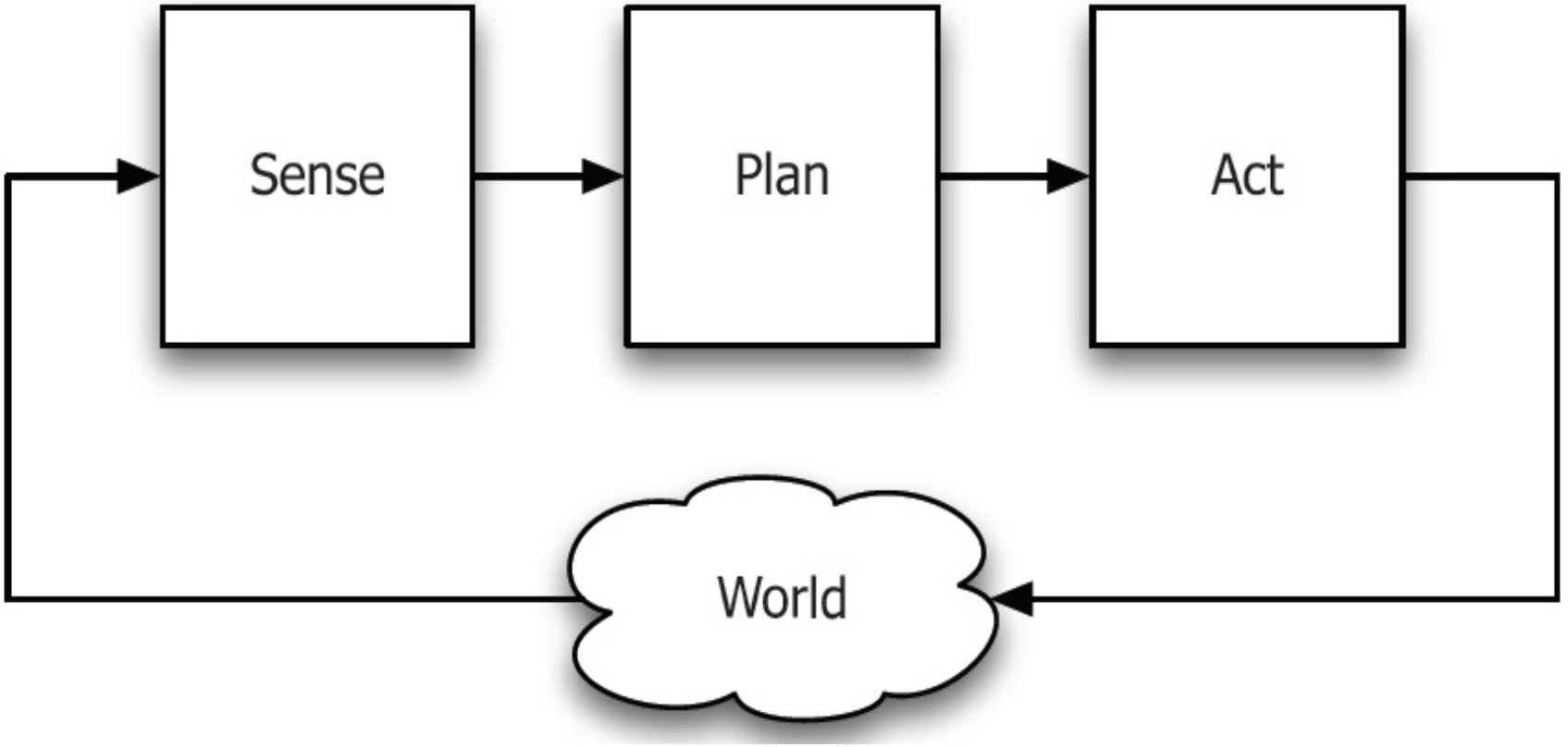
- Deliberative control
- Reactive control
- Hybrid control
- Behaviour-based control

Deliberative Architecture

- Maps, lots of state
- Look-ahead



Control Decomposition: Sense-Plan-Act



High-level planning: Planning problems

Example high-level planning problem:

Initial state:
`at(boxA,place2),at(boxB,place2),at(robot,place3)`

Goal state description:
`at(boxB,place1),at(boxB,place2)`

Also need a domain description with:

- Possible actions.
  - Action preconditions.
  - Action effects.

Example plan

Example plan:

```
1 STATE: at(boxA,place2),at(boxB,place2),at(robot,place3)
  ACTION: go(place1,place2)

2 STATE: at(boxA,place2),at(boxB,place2),at(robot,place2)
  ACTION: push(boxA, place2, place1)

3 STATE: at(boxA,place1),at(boxB,place2),at(robot,place1)
  ACTION: go(place1,place2)

4 STATE: at(boxA,place1),at(boxB,place2),at(robot,place2)
  ACTION: push(block2, place2, place1)

5 STATE: at(boxA,place1),at(boxB,place1),at(robot,place1)
  DONE
```

Example action description

Move from place to place in a room:

go(X,Y):

- PRECONDITIONS:
  - at(robot,X)
- ADD EFFECTS:
  - at(robot,Y)
- REMOVE EFFECTS:
  - at(robot,X)

Example action description

Push movable objects within a room:

push(B, X, Y):

- PRECONDITIONS:
  - at(B,X)
  - at(robot,X)
- ADD EFFECTS:
  - at(B,Y)
  - at(robot,Y)
- REMOVE EFFECTS:
  - at(B,X)
  - at(robot,X)

Finding plans

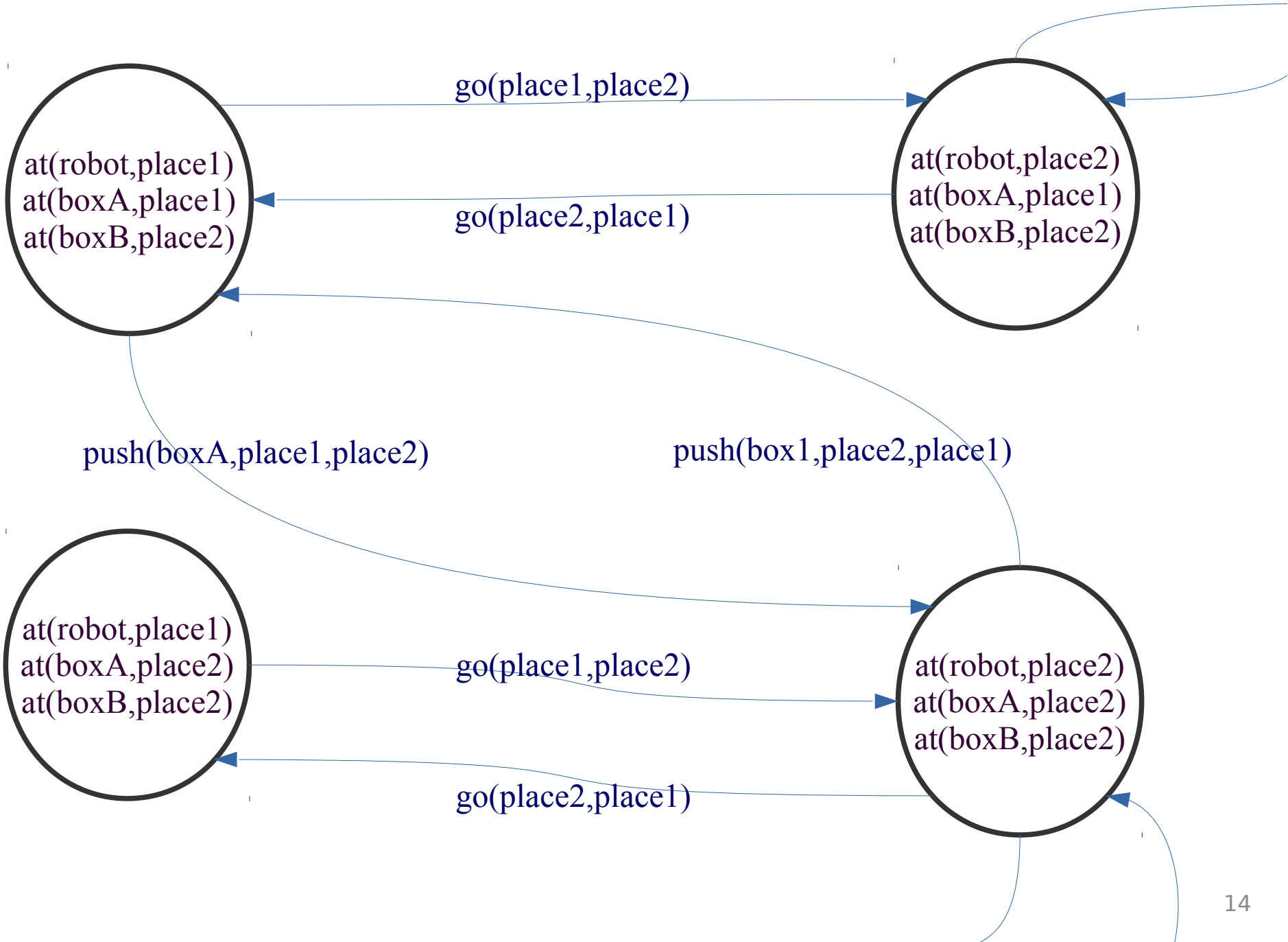
- Given:
  - Domain description (available actions).
  - Goal description and initial state.
- Find:
  - Sequence of actions.

- Approaches:
  - First-order logic & theorem-proving.

    → SEARCH
  - General purpose planners.

    → SEARCH

Example state subgraph



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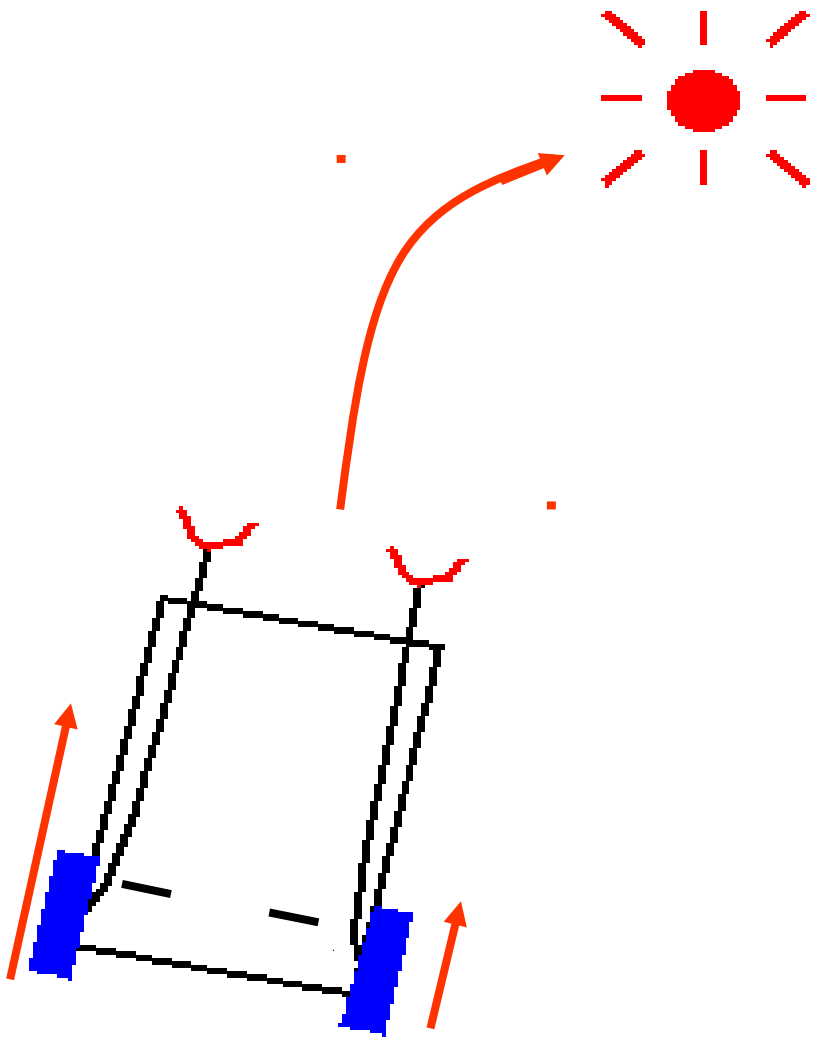
Reactive Architecture

- No maps, no state
- No look ahead
- Could be implemented by a look-up table

Braitenberg Car

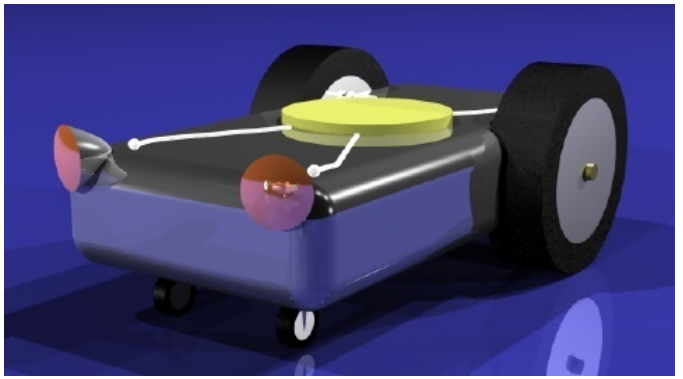


- By default, the motors turn!
- Each sensor is connected to the motor on the

  same side inhibiting the motor.
- The vehicle
  - heads toward light sources
  - speeds up in dark areas
  - slows down in light areas
  - spends more time in light and less time in dark.

Braitenberg Car

- appears to have goals
- does not possess states (current velocities)
- characterized as: “loves” light.



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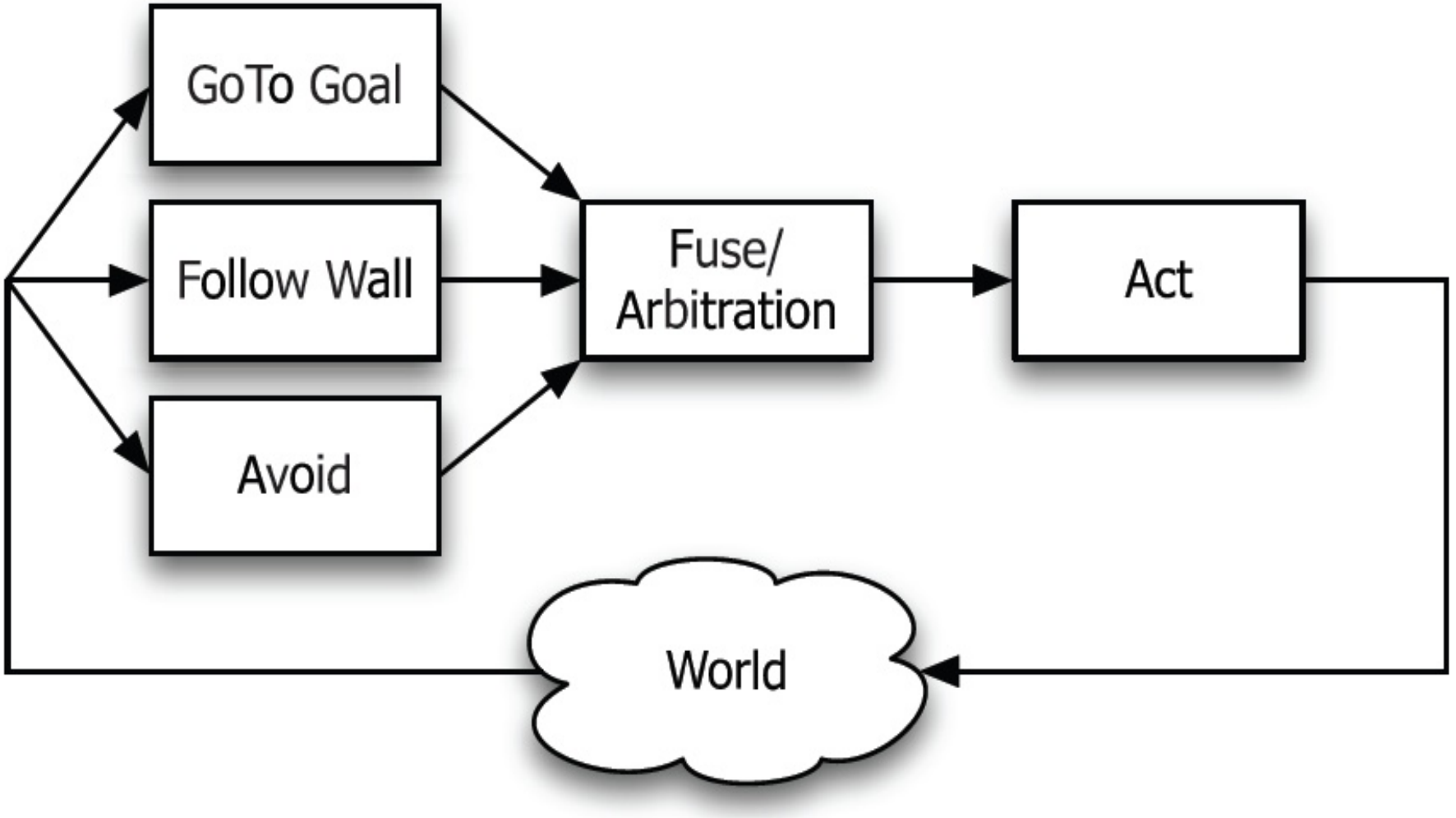
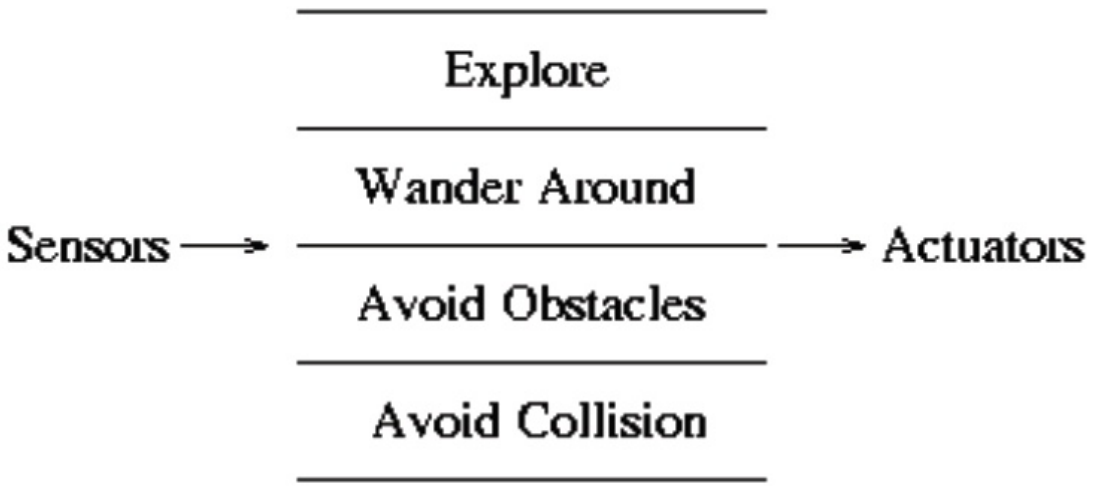
Parallel Decomposition - Behavioural



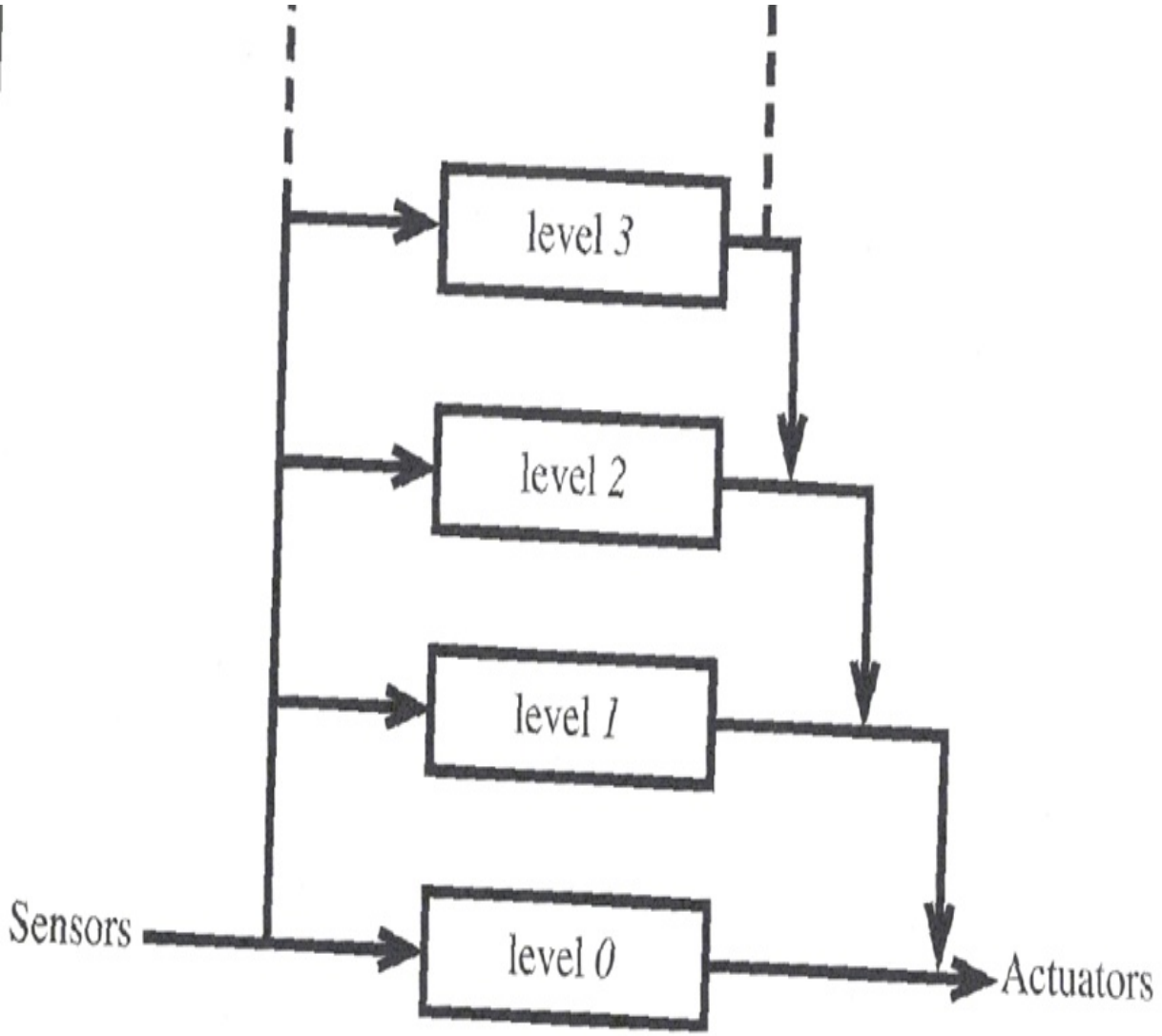
Behaviour-based Architecture

- Some state.
- Look ahead only while acting.
- Reactive + state.



Combining modules does not give any guarantees of correctness (not easy to formally model)

Layered (incremental) control: Subsumption architecture



- Higher level layers subsume roles of lower layers when they take control.
- Layers below any level form a complete operational control system.

Mobile robot example

- Level 0: Avoid objects.
- Level 1: Wander aimlessly (without hitting).
- Level 2: “Explore” head towards distant places.
- Level 3: Build map, plan routes.
- Level 4: Notice changes in map.
- Level 5: Reason about objects and tasks.
- Level 6: Formulate plans.
- Level 7: Reason about object dynamics.

Mobile robot example

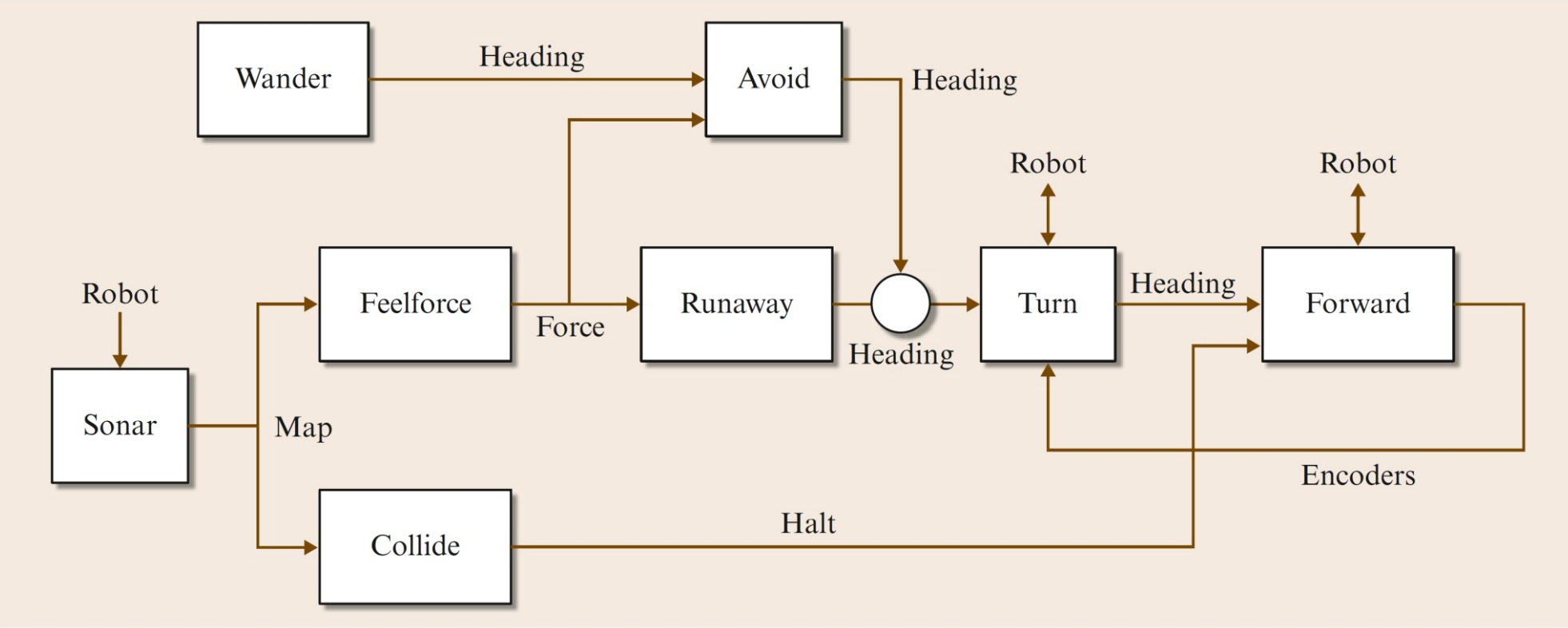
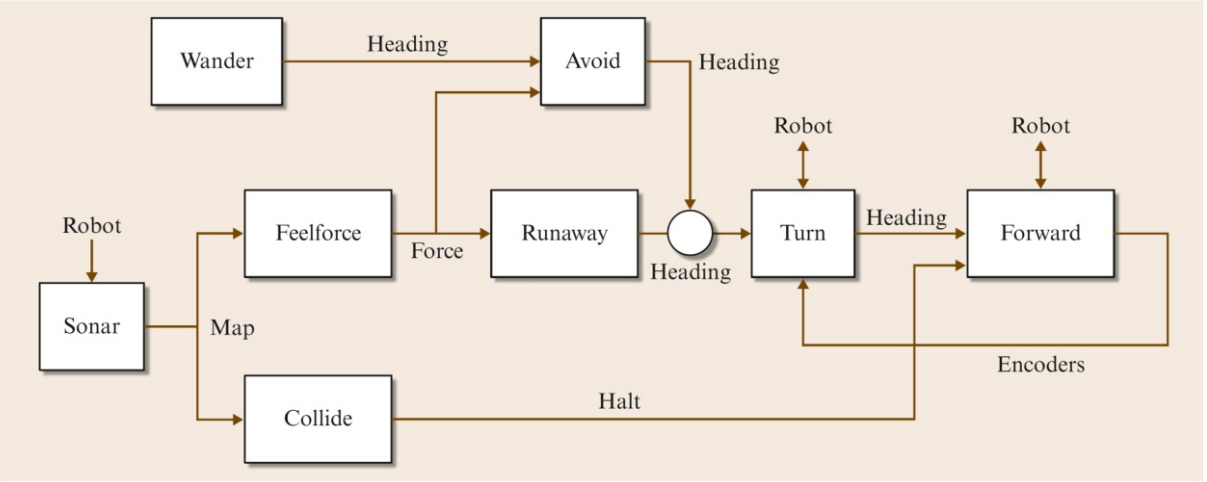


**Figure courtesy of Handbook of Robotics, Springer, 2008*

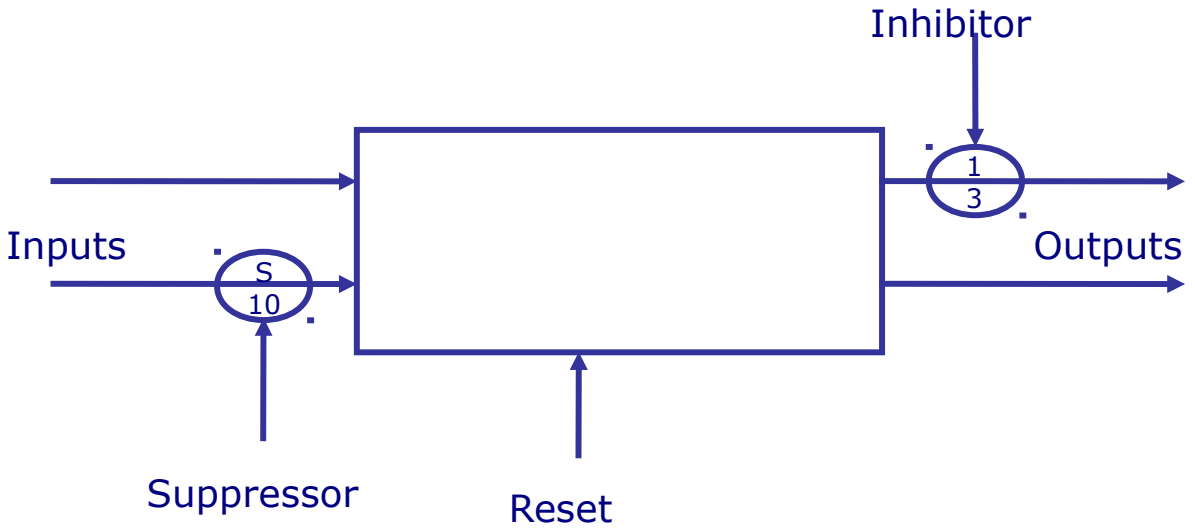
Mobile robot example

- sonar: Vector of sonar readings → robot-centered map of obstacles.
- collide: Map → detects objects ahead → halt signal.
- feelforce: Obstacle map → repulsive force.
- runaway: Repulsive force → heading.
- turn and forward: Feedback control from encoders.
- wander: Random movement generation.
- avoid: Reactive avoidance: Combine feelforce and wander.



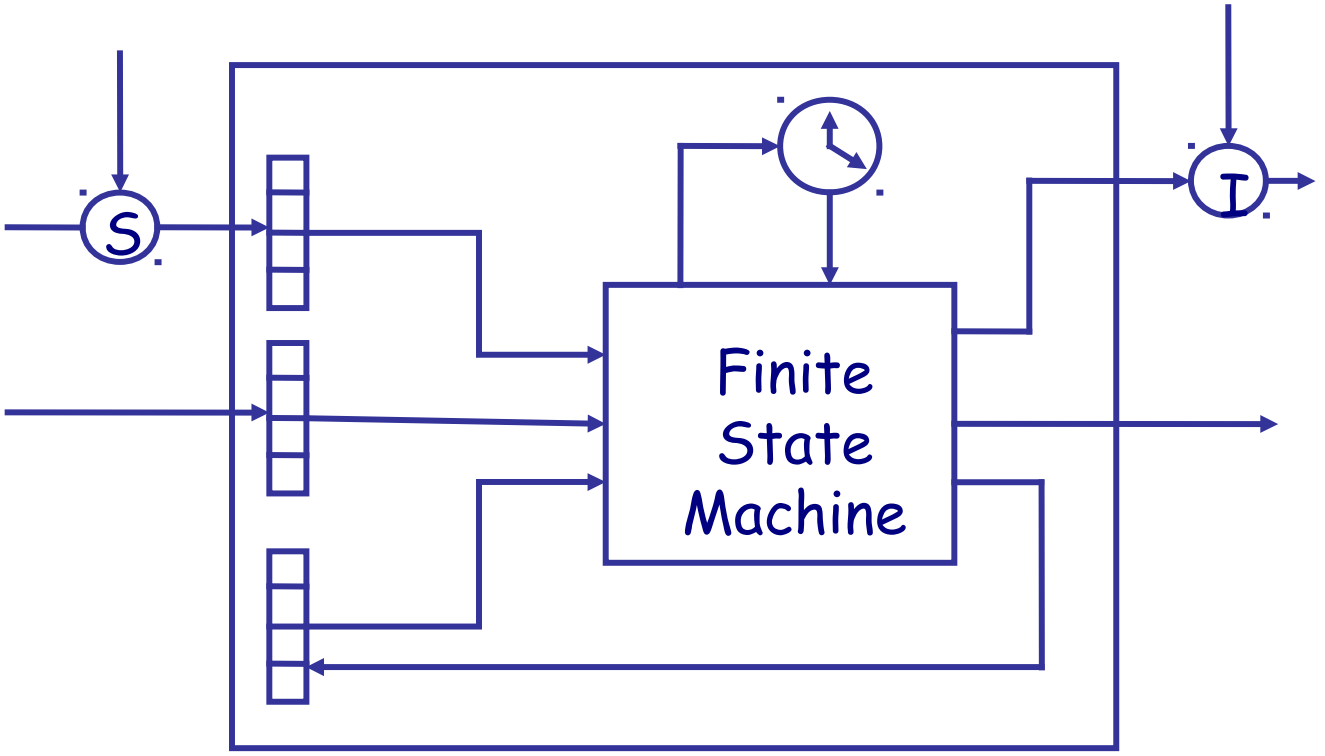
Subsumption Modules

- Input and output lines: “wires”.
- 1-message buffer.
- Suppression of inputs or inhibition of outputs.
- Can be reset.



Augmented Finite State Machines

Message arrival/timer expiration → trigger a change in the state of FSM.



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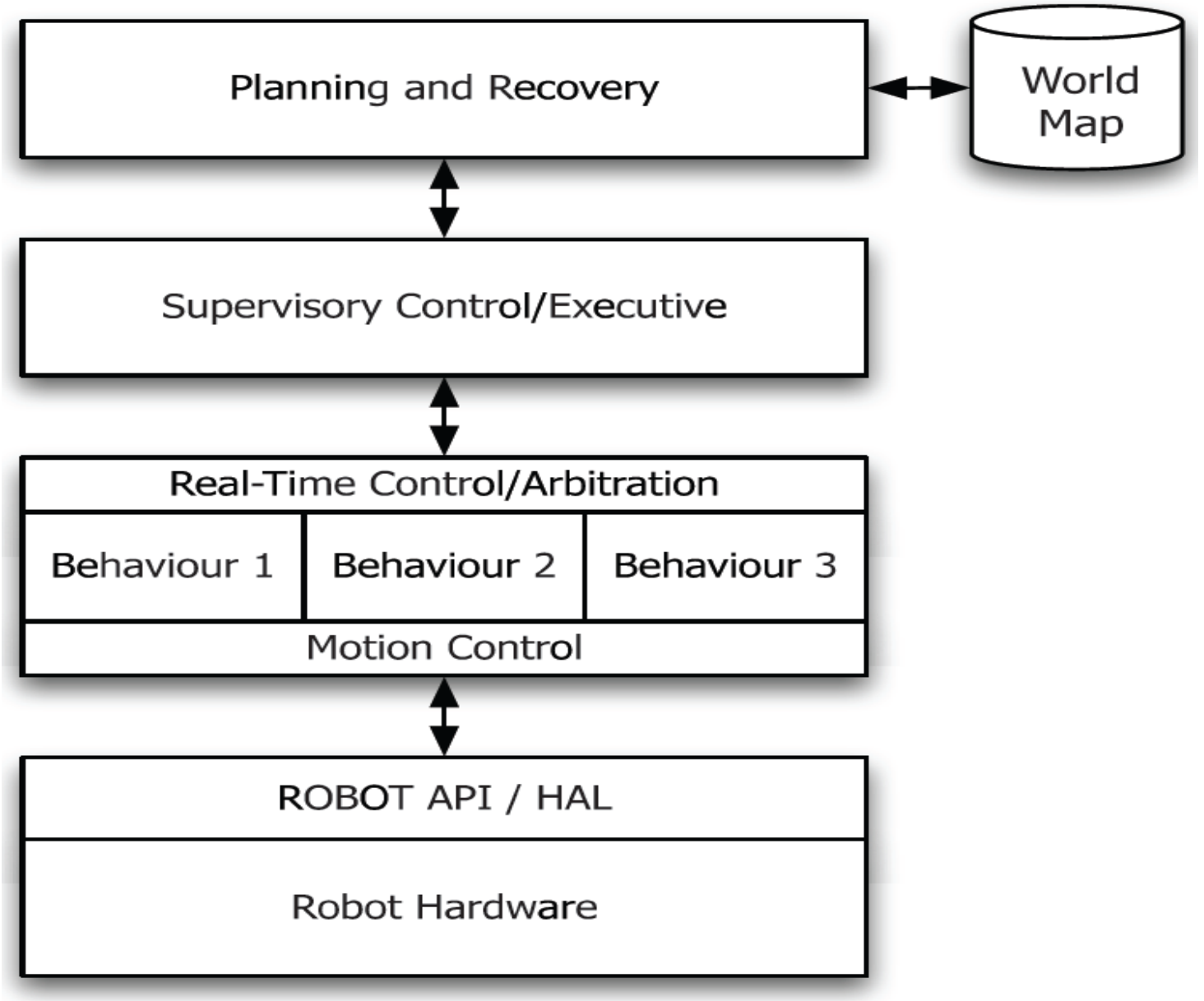
Hybrid Architectures

- State.
- Look ahead but react.
- Combines long and short time scales.

- Interleaves deliberation (planning) with reactive control – e.g. moving obstacle avoidance.
- Very common nowadays.

Hybrid Architectures



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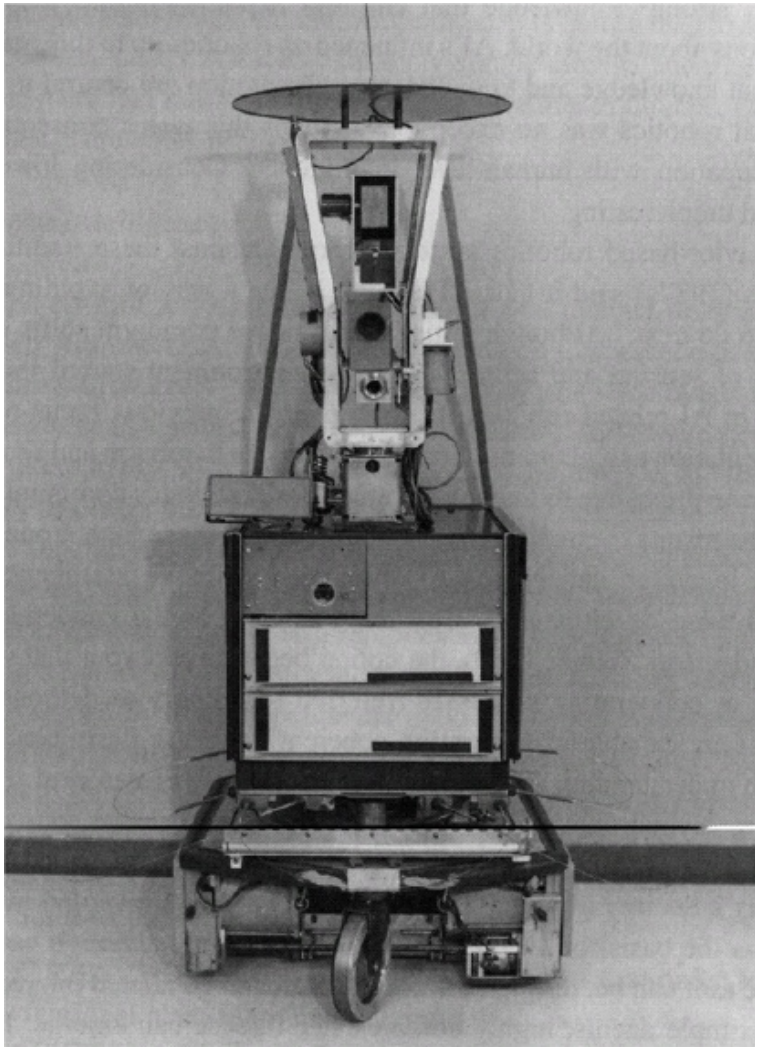
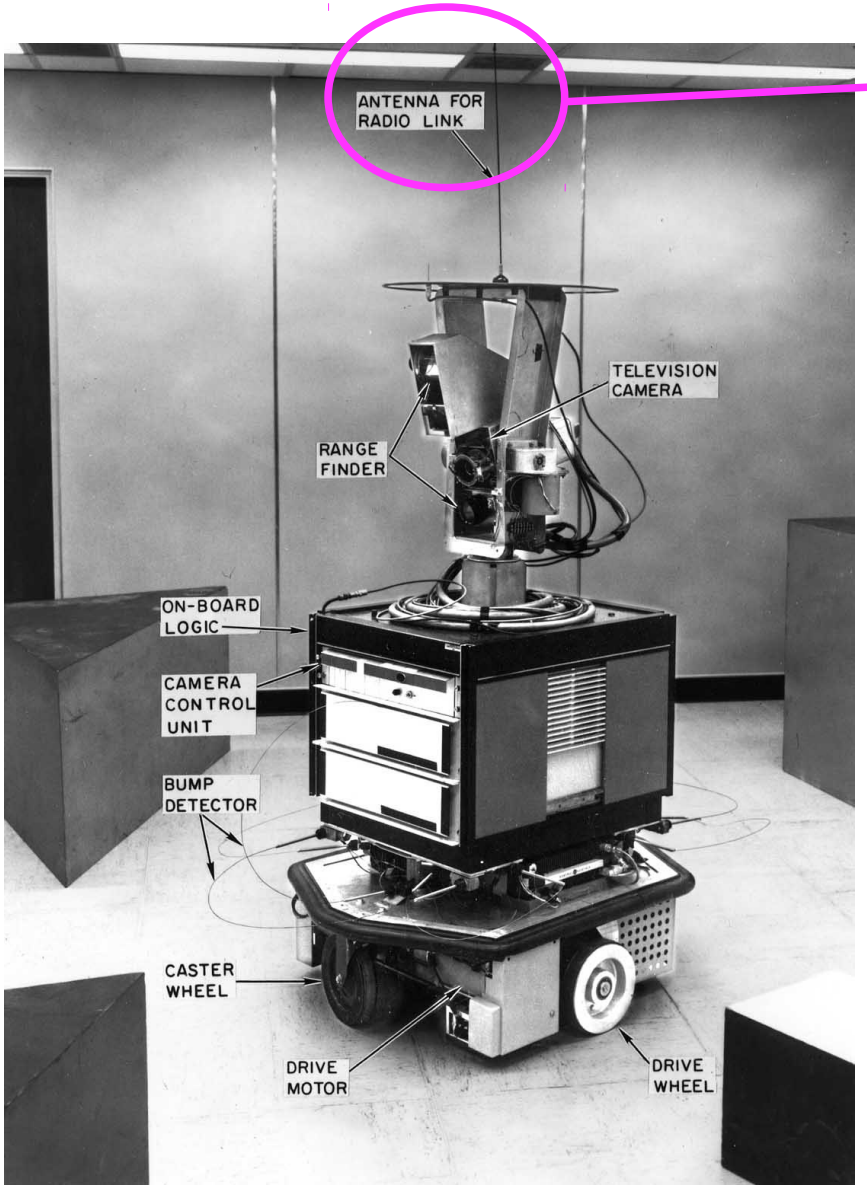
Early robots - Shakey

Shakey (SRI), 1960's

- Sensors:
  - VidiconTV camera
  - Optical range finder
  - Whisker bump sensors
- Environment: Office environment with specially colored and shaped objects
- STRIPS planner: developed for this system

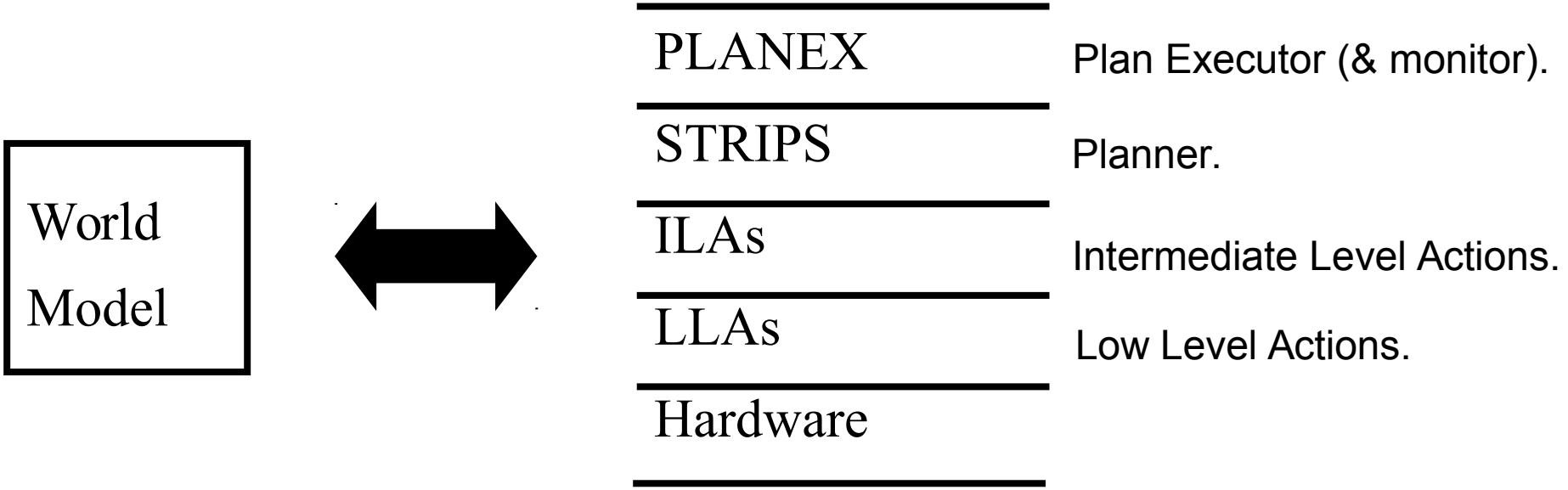


Shakey the robot



To controlling computer

Shakey outline



- Central representation (world model)
- Logic based representation.
- Components communicate via world model.
- Error recovery at several levels (e.g. plan executor, low level actions).

(strictly speaking, a hybrid approach)