

# Hybrid architectures

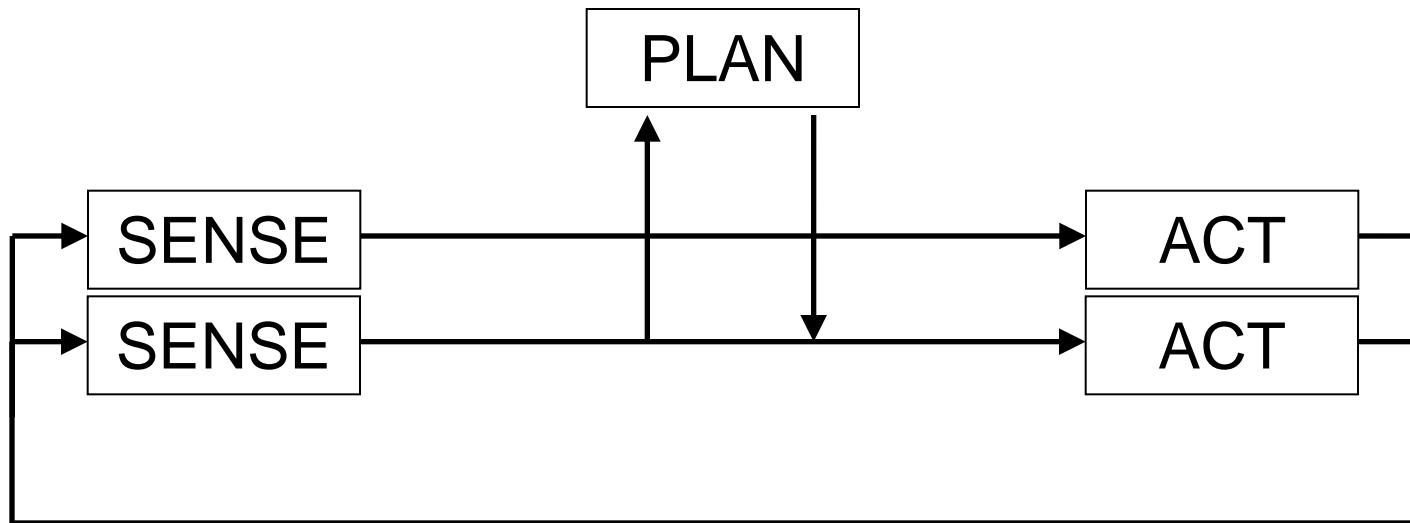
IAR Lecture 6

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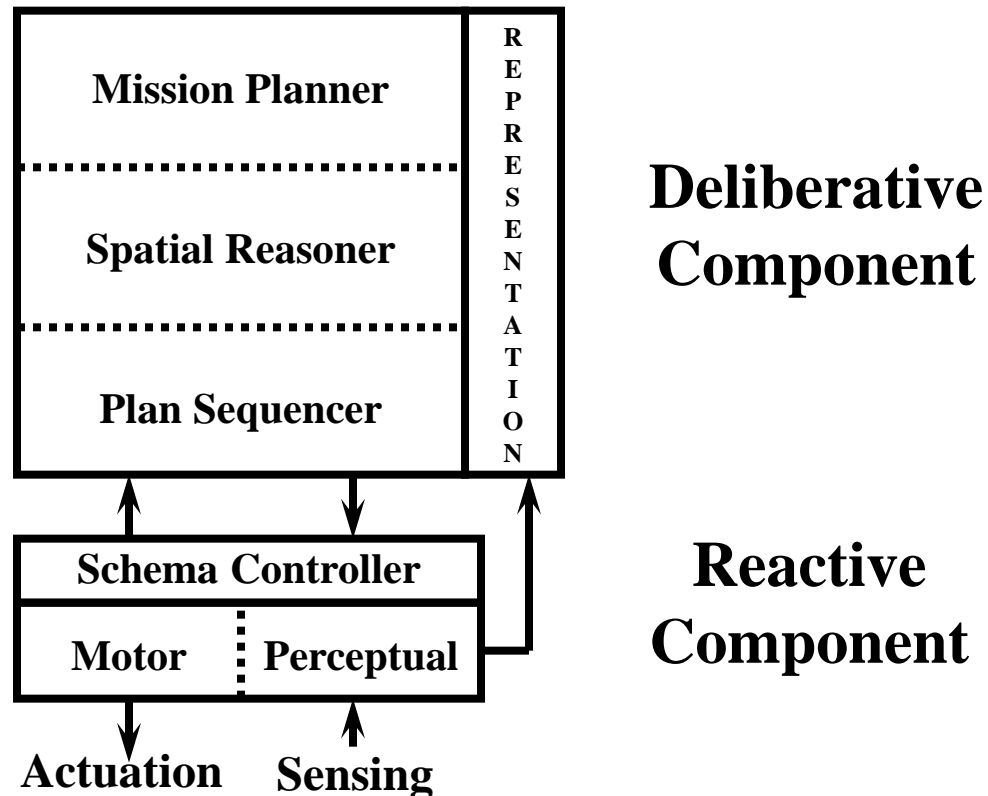
# Can we get the best of both worlds?

- Behaviour-based architectures, using combinations of reactive controllers, rather than reasoning over world models, seem to be robust, real-time, modular – good for robot control.
- But may still want world models and traditional reasoning for path planning, map making, performance monitoring, problem solving...
- And have introduced new problem of how to compose behaviour interactions
- **Solution:** have the robot itself intelligently select, sequence or assemble behaviours to achieve a task

# Introduce high-level capabilities without losing low-level advantages



# AuRA: Autonomous Robot Architecture (Arkin, 1997)



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- **Mission planner:** determines current goal
- **Spatial reasoner:** produces sequence of path legs to traverse
- **Plan sequencer:** translates each path leg into a set of behaviours – linking sensor and motor schemas
- **Schema manager:** starts, stops and monitors schema execution

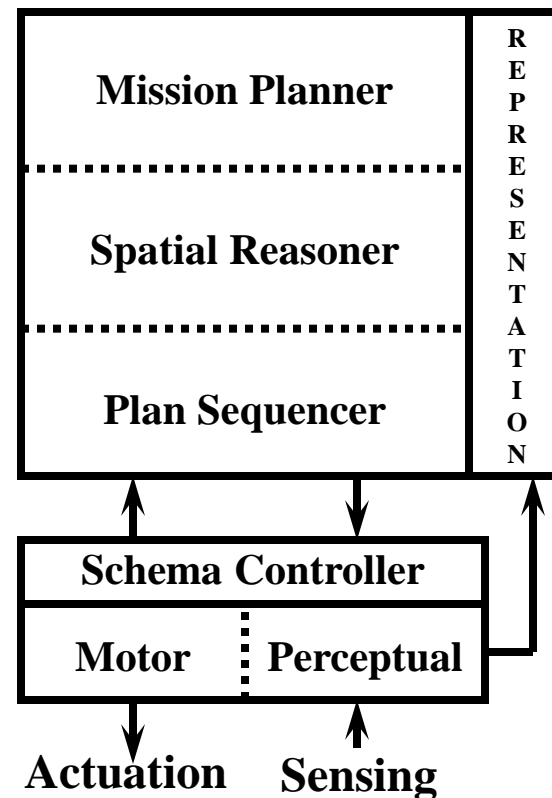
As for the basic schema architecture (see lecture 5), the robot's action is the weighted sum of motor schema vector outputs

# AuRA: Autonomous Robot Architecture (Arkin, 1997)

- Once reactive execution begins, deliberation is de-activated, unless detect failure.
- Failure recovery works up the hierarchy:
  - Revise plan sequence based on input so far
  - Have spatial reasoner devise new route
  - Have mission planner revise goals

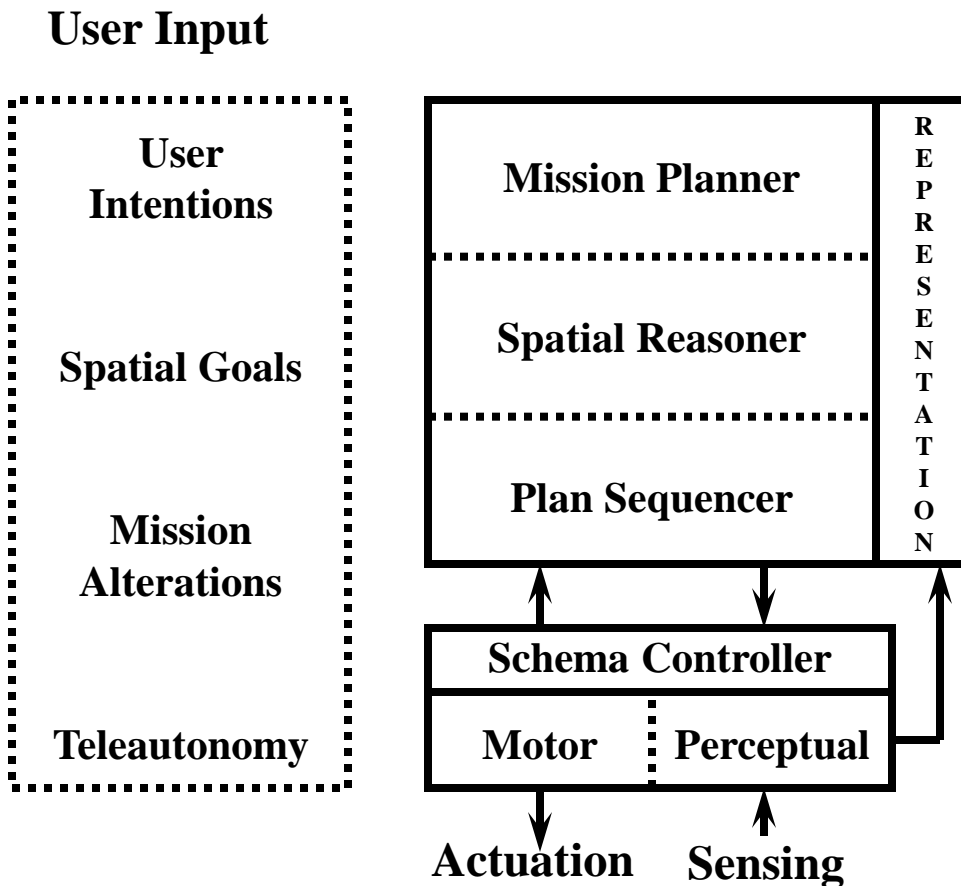
# AuRA: Autonomous Robot Architecture (Arkin, 1997)

Potential to substitute improved methods at each level independently



# AuRA: Autonomous Robot Architecture (Arkin, 1997)

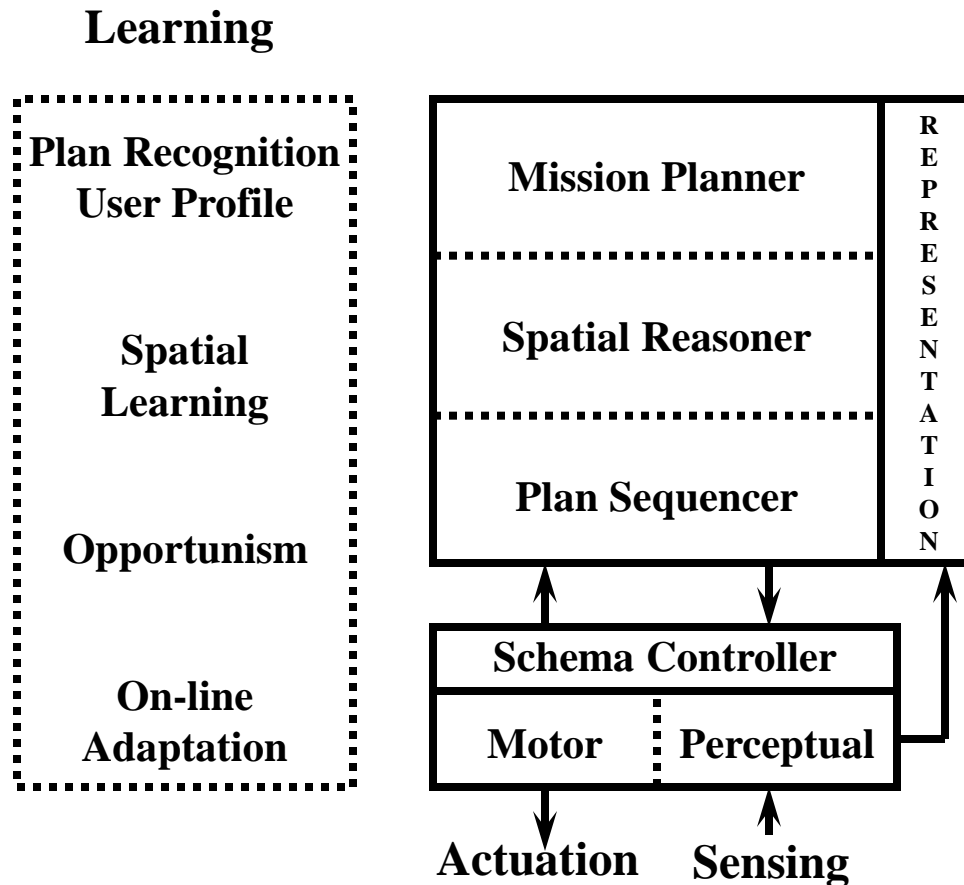
Rich options  
for user  
interaction



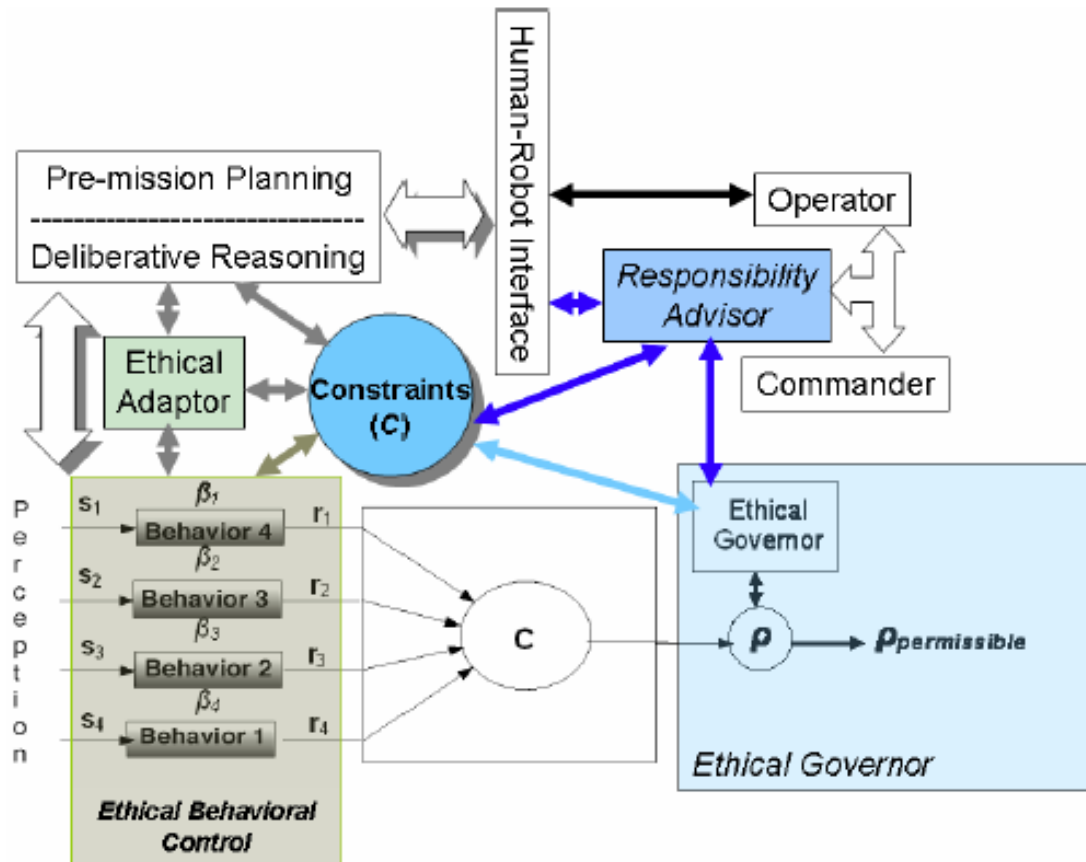


# AuRA: Autonomous Robot Architecture (Arkin, 1997)

Can introduce  
learning  
mechanisms  
at different  
levels

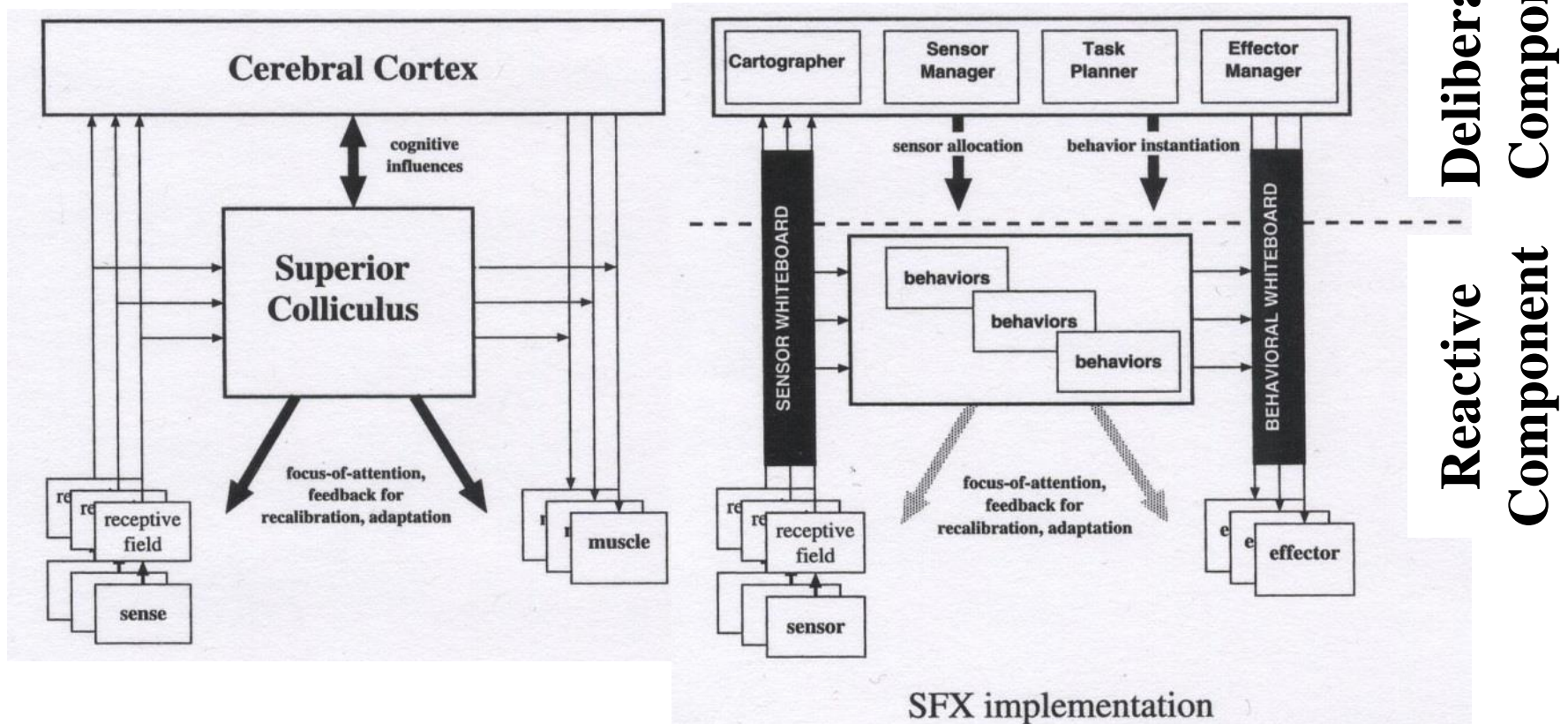


# Embedding ethical control (Arkin, 2009)



# SFX: sensor fusion effects (Murphy, 2000)

Biomimetic inspiration for hybrid architecture

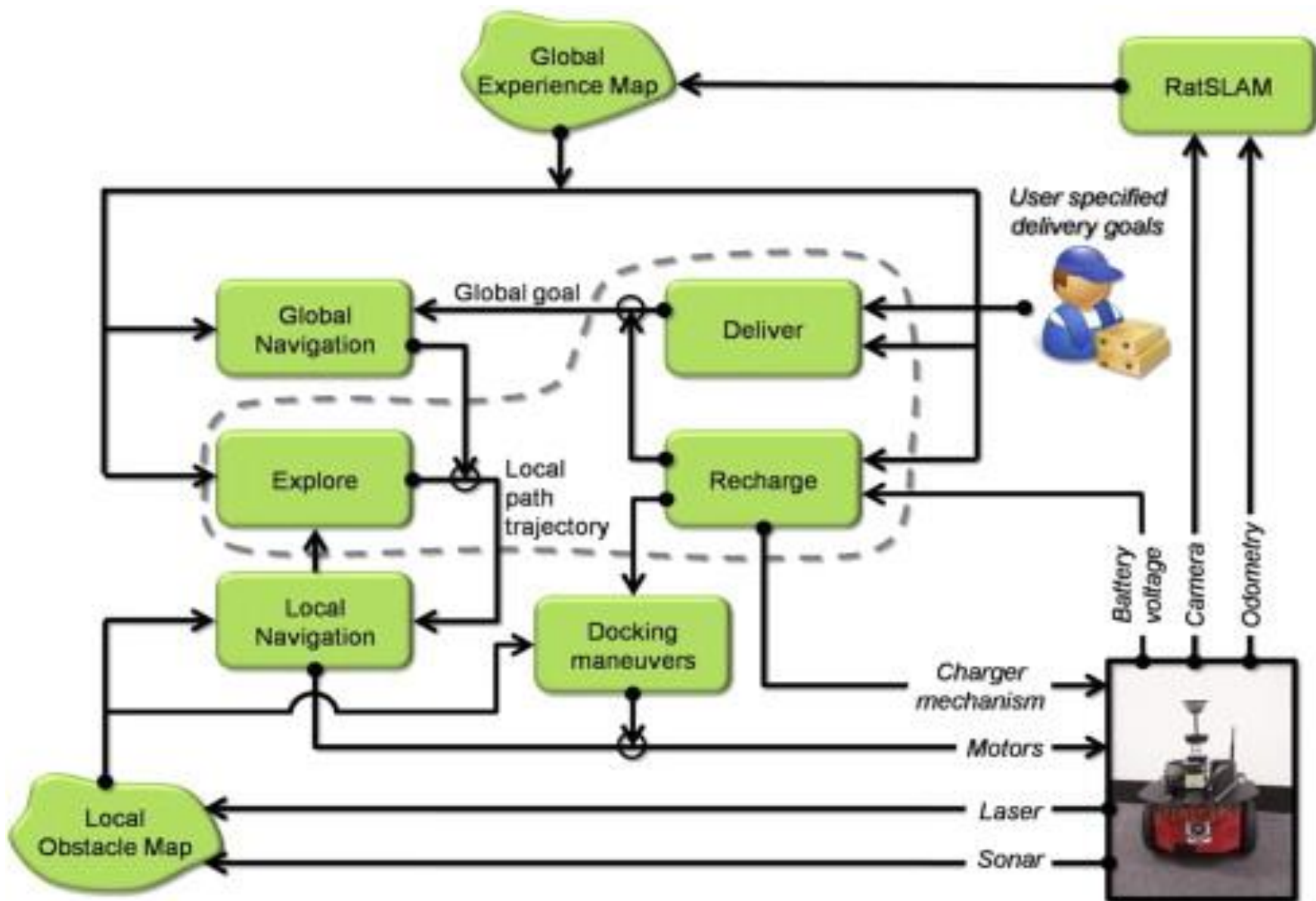


# Low level behaviours can support abstractions that simplify planning

- Planning is difficult because of uncertainty
  - Precise location of robot and things around it
  - Accuracy/repeatability of robot actions
  - Adequacy/reliability of sensor data
- **Solution:** If can off-load uncertainty handling to low level behaviours, planning becomes much more tractable

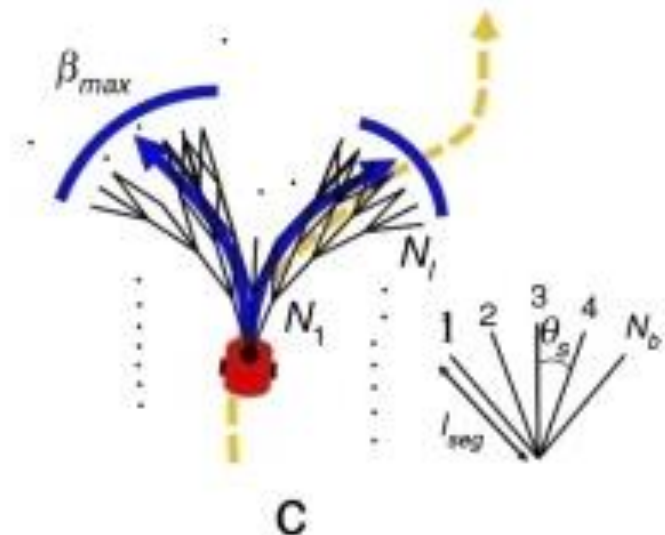
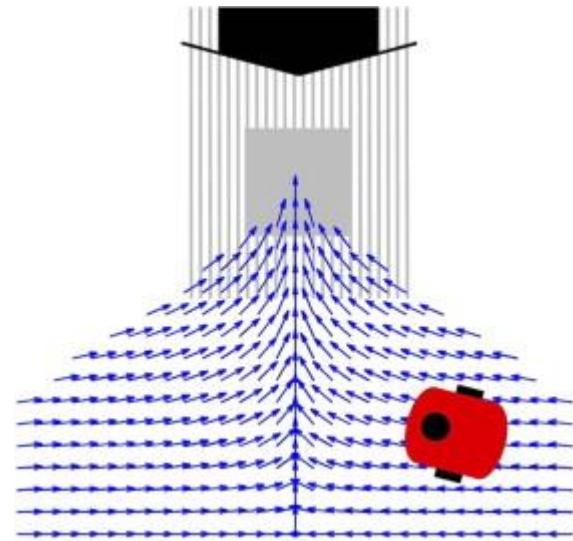
# Hybrid control for navigation (Milford & Wyeth 2010)

- Use of low-level immediate sensing to build high-level map.
- Effective if same control system is used in both creating and using this world representation.
- Robot placed in new office building environment, learns map (including its charger location) then makes deliveries – continuously operating over two weeks in dynamic environment.



# Milford & Wyeth (2010)

- Reactive docking procedure (potential field method) relies on assumption that recharge and global navigation have brought robot to suitable starting position
- Local obstacle avoidance generates safe trajectories, clusters these and takes midpoints. Comparison to trajectory desired by explore or global navigation determines choice of robot action



# Temporal task decomposition

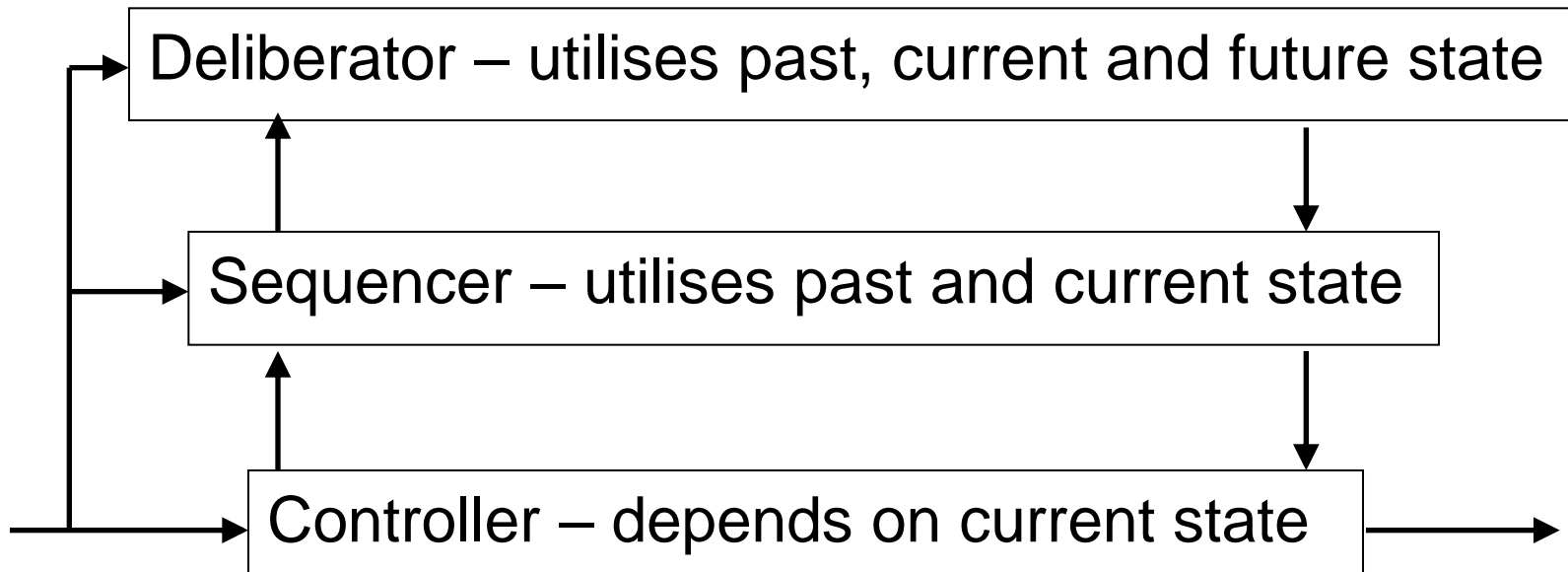
- One basic problem with the traditional sense-plan-act was that planning is slow, and the internal state gets out of synchrony with reality
- Reactive solution of minimal internal state increases risk of mistakes due to sensor error
- **Solution:** Use parallel layers to maintain internal states appropriate to the different speeds of processing



# Temporal task decomposition

Offline/episodic reasoning	Map-based path planning	0.01Hz
Strategic decisions	Range-sensor based obstacle avoidance	1 Hz
Real time control	PID speed	100Hz

# Three-layer architecture (Gat 1998)



# Three-layer architecture (Gat 1998)

## **Controller:**

- Behaviour library of handcrafted sensorimotor transfer functions (e.g. wall follow – with appropriately oriented sonar, servo on distance to wall)
- Must be fast enough for stable closed loop control
- Should avoid internal states, or use ephemeral states (e.g. filter sonar by rejecting sudden increases in distance)
- Internal state should not introduce behavioural discontinuities (these should be new behaviours)

# Three-layer architecture (Gat 1998)

## **Sequencer/Executive:**

- Selects which behaviours are active
- Not just following fixed sequence but responds to situation in interpreting any plan
- Does not search into future to decide action
- Should not take a long time, relative to the environment and the behaviours
- E.g. in maze, first find wall; then follow it to confirm is wall not obstacle; then remember sequence of turns

# Three-layer architecture (Gat 1998)

## **Deliberator:**

- Does any time consuming computations
  - Typically plans
  - May include complex sensor processing (e.g. vision)
- Running as separate thread/on separate processor
- Can either produce a plan for the sequencer, or respond to sequencer requests for deliberation
- E.g. in maze, compare sequence of turns to stored map; once recognise the location, plan moves to reach exit

# Three-layer architecture (Gat 1998)

- *“lines between the components of the three layer architecture can be blurred to accommodate reality”*
- *“If, as seems likely, there is no One True Architecture, and intelligence relies on a hodge-podge of techniques, then the three layer architecture offers itself as a way to help organise the mess”*

# Hybrid architectures

- Most robotic approaches today use some form of hybrid architecture, combining low-level reactivity with higher level reflection, in multiple parallel modules
- Many variants, and tendency towards ‘hodge-podge’ solutions in real applications
- Substantial speed up in planning methods has made it more viable to include within real time control loops
- Also improvements in sensor algorithms & state estimation methods, so internal models more reliable
- Example: Stanley, winner of 2005 DARPA Grand Challenge (Thrun et al 2006)

## References:

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