

On Three Layer Architectures (Erann Gat)



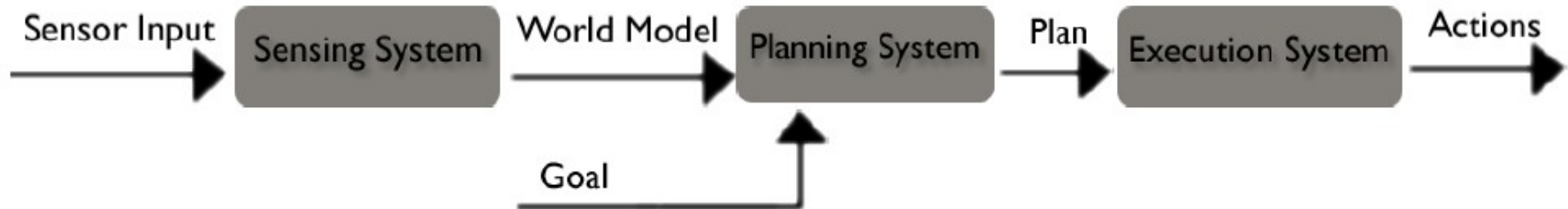
Matt Loper / Brown University
Presented for CS296-3



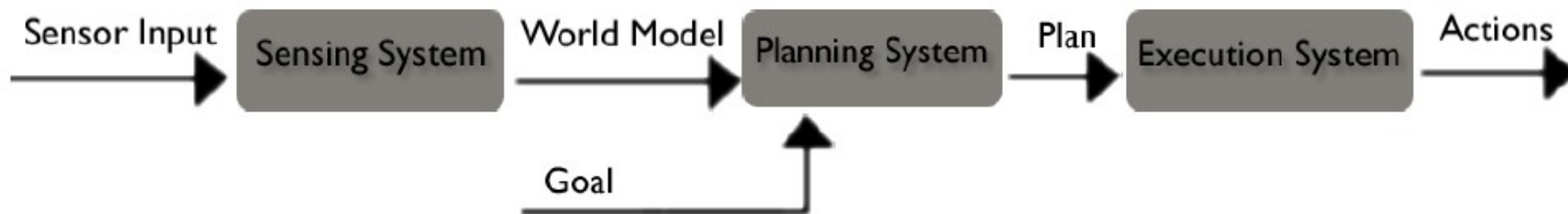
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- What is a good control architecture for a robot?
- How should it coordinate long and short-term thinking?
- Motors and sensors?
- What is the best information flow?
- Example: consider robocup

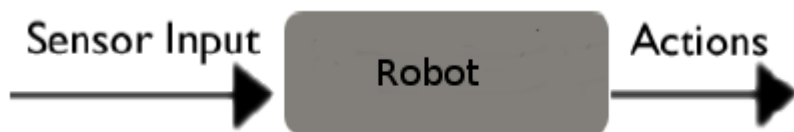
- [Nilsson, 1980]
- Unidirectional flow of information: nice!
- Why is this bad?
 - Dominant view in early 1980s



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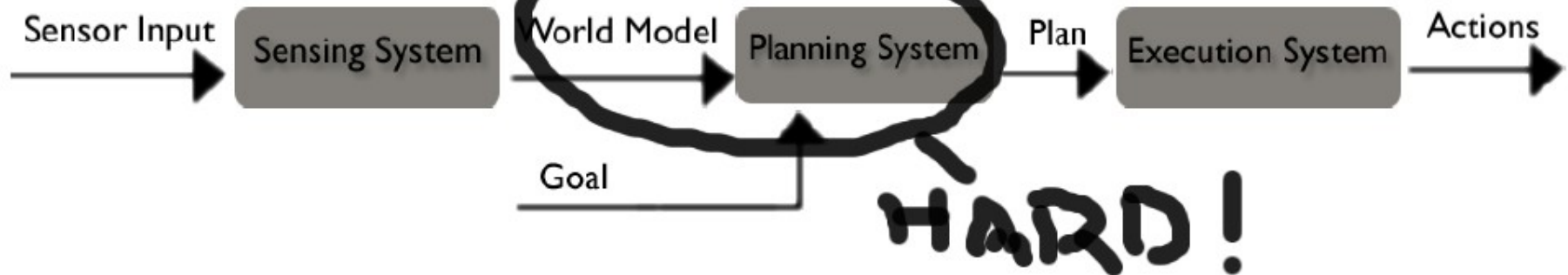


- Why is this bad?



- Think about good software design
 - Encapsulation: equal amounts of complexity in each box
 - Testing: test low-level systems first

- Dominant view in early 1980s



Brook's subsumption idea

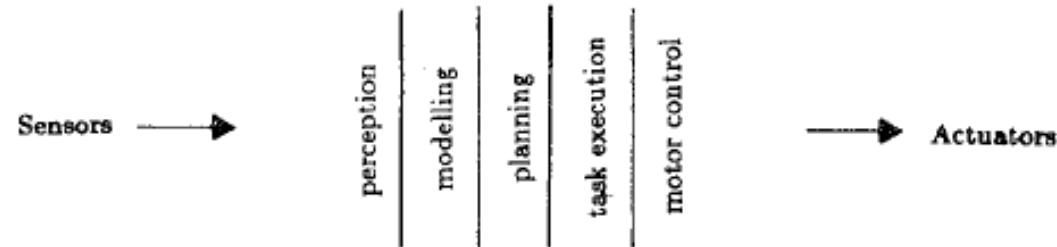


Fig. 1. Traditional decomposition of a mobile robot control system into functional modules.

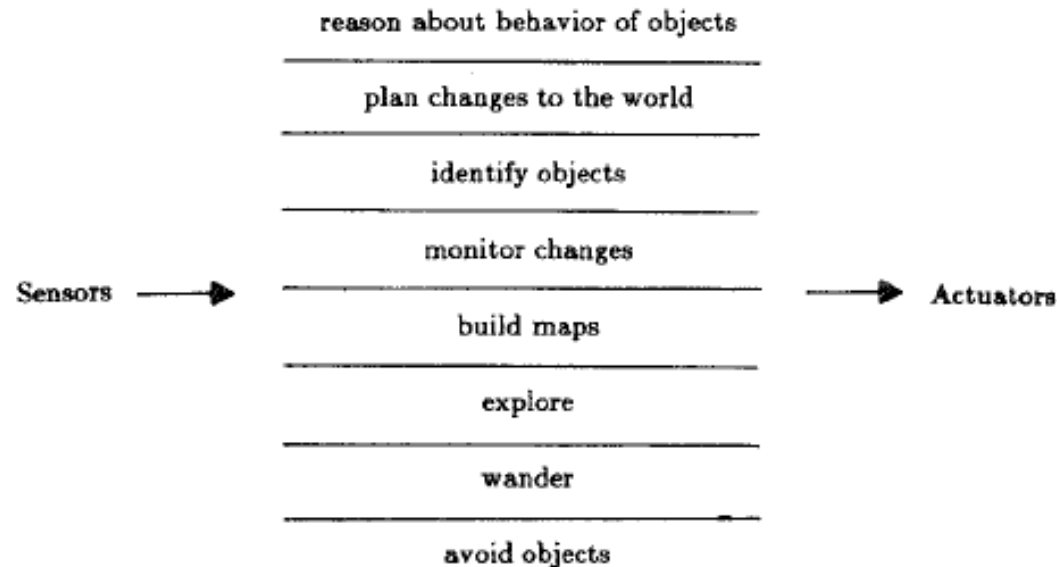


Fig. 2. Decomposition of a mobile robot control system based on task-achieving behaviors.

Brook's subsumption idea

- Brook's paper introduced a number of interesting ideas
- Asynchronous communication from different processors in system
- Inhibition of inputs/outputs of lower layers, by upper layers

Brook's subsumption idea

- A simple robot...

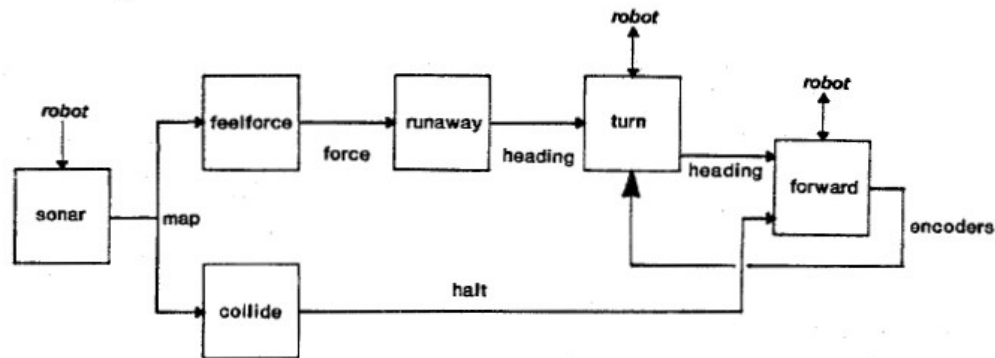


Fig. 5. Level 0 control system.

Brook's subsumption idea

- A wandering robot...

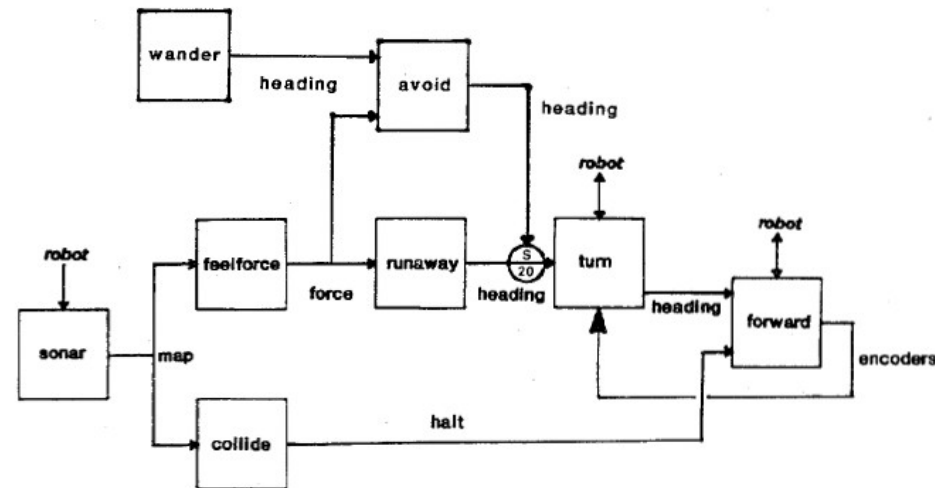


Fig. 6. Level 0 control system augmented with the level 1 system.



Subsumption: What went wrong?

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- Not sufficiently modular
 - higher-level modules would be intimately involved in details of low-level modules
- Simplistic
 - Sometimes, low-level modules should get to interrupt high-level modules
- Not so “taskable”: hand-coded connections may make flexibility low

3-Layer Architectures

- In 1991, three groups all came up with basically same approach [Connell91, Gat91, Bonasso91]
- Split the architecture into three modules:
 - Deliberative planner
 - Sequencer – more on this later
 - Reactive feedback controller
- Why three modules? What is the magic here?

- Why three modules?
- Consider different kind of decisions:
 - Some require only sensory input, no state
 - Some require memory of the past
 - Some require both of the above, *and* planning about the future
- Hence three layers
 - Deliberative planner: plans for the future
 - Sequencer: remembers the past
 - Reactive feedback controller: stateless

3-Layer Architectures

- Consider also the separate issue of time/space complexity
- Hence three layers
 - **Deliberative planner:** input is the past and the potential future. May take lots of time in executing long, memory-intensive operations that span many behaviors
 - **Sequencer:** remembers the past, and must be faster
 - **Reactive feedback controller:** should be extremely fast

Did Freud invent this?

- Freud divided the psyche into “id”, “ego”, and “super-ego”
 - Id: inborn, unconscious instincts
 - Ego: mediates between the id and super-ego
 - Super-ego: intellectualism, morality
- **Question:** Did Freud invent the 3-layer architecture?

Did Freud invent this?

- Freud divided the psyche into “id”, “ego”, and “super-ego”
 - Id: inborn, unconscious instincts
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- **Question:** Did Freud invent the 3-layer architecture?
- **Answer:** no, pretty unrelated
 - Freud thought everything was about sex

The 3-layer architecture

- Now let's look at the parts
 - Reactive Controller
 - Sequencer
 - Deliberative

- Lowest level module
- Has programmable “Behaviors”, such as...
 - Wall-following
 - Collision avoidance
 - Moving through doorways
- This module should be
 - fast, low/memory
 - able to detect failures and deal with them
 - without internal state

- Select primitive Behavior, and supply parameters to that Behavior
- Has some state about the past
- Performs tasks that do not require planning

- Can either send tasks to sequencer, or just respond to sequencer queries, depending on application
- Example problem spaces:
 - Localization
 - Path Planning
 - Motor Planning

The Debate: Planning vs. Reacting

- What's the debate again?
- “Some of this passion may be the result of a hidden conviction on the part of AI researchers that at the root of intelligence lies a single, simple, elegant mechanism. But if, as seems likely, there is no One True Architecture, and *intelligence relies on a hodgepodge of techniques [my emphasis]*, then the three-layer architecture offers itself as a way to help organize the mess”

What this paper doesn't cover

- The paper doesn't cover a number of important issues:
 - Sensor processing
 - Learning
 - World modeling
- But its take-home message is good;
 - Algorithms seems to fall into three groups based on time-dependency (stateless, sequencing, or deliberative)
 - Still build and test from the bottom up

- Eran Gat. “On Three-Layer Architectures.” Artificial Intelligence and Mobile Robotics, in D. Kortenkamp, R. P. Bonnasso and R. Murphy (eds.), AAAI Press, pages 195-210, 1998.
- Rodney A. Brooks. “A Robust Layered Control System for a Mobile Robot.” IEEE Transactions on Robotics and Automation, 2(1), pages 14-23, April 1986.
- Stole diagram from:
 - <http://dora.eeap.cwru.edu/msb/591/3layer.pdf>