Behaviors II – *Thinking*

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"Thinking"… Selecting Actions

- Sensory data as input
- "Behaviors" as *processing of input to select actions*
- Actuators perform the actions

Perception, Cognition, Action

- Deliberative – three levels
  - Sense:
    - Construct *world state* from sensory data
  - Plan
    - Find a *sequence of actions* that lead from world state to a *goal*
  - Act
    - Transform planned actions for *execution by actuators*

Environment/Domain Issues

- Sensory accuracy
  - How reliable is the sensory input?
- Time
  - How much time is there "to think, plan"?
- Goal
  - How defined are the goals?
- Dynamics
  - How "worth" is to think ahead?

Advantages/Disadvantages of Deliberative Approach

- A plan.
- Let's brainstorm together.

Perception, Cognition, Action

- Reactive – two levels
  - Sense:
    - Process sensory data into sensory information
  - *No plan*
  - Act
    - Sensory information is the direct input for *execution by actuators*

Advantages/Disadvantages of a Reactive Approach

Advantages
- Very responsive to changes in environment
- Smooth control changes in response to smooth changes in sensor values

- Disadvantages
  - Can’t perform different actions from the same state
  - Can get stuck
  - Don’t scale well to complex tasks

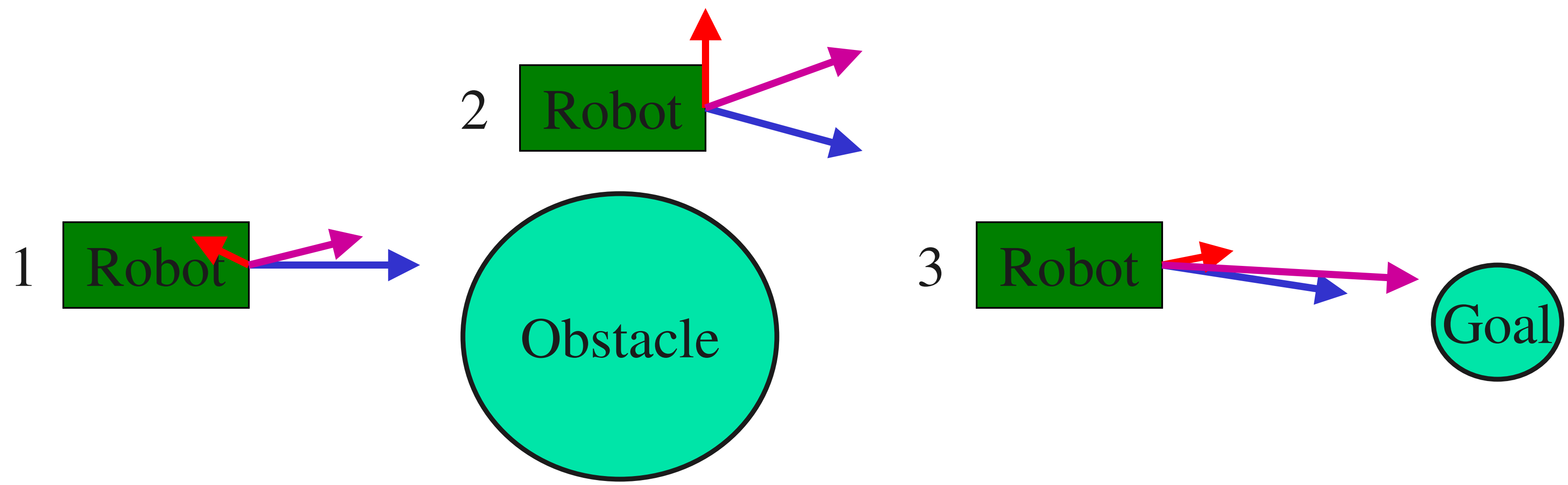
Memory in Reactive Approach?

- What does it mean to have *memory*?
- Brainstorm:
  - State, Markov, single observation, history of observations

Combining Reactive Behaviors

- Blending
  - Efficient if sensor values can be mapped into activation values easy to combine as "forces"
  - Problem: equal but opposing forces can cancel each other out
- Competition
  - Similar to blending, but introduces "winner" behavior
  - Problem: possible oscillations
- Subsumption
  - Provide a strict hierarchical priority ordering for the behaviors
  - Problem: very dependent on definition of hierarchy
- Sequencing
  - Run a single reactive behavior and change with state – FSM
  - Problem: state granularity

Blending: Motor Schemas

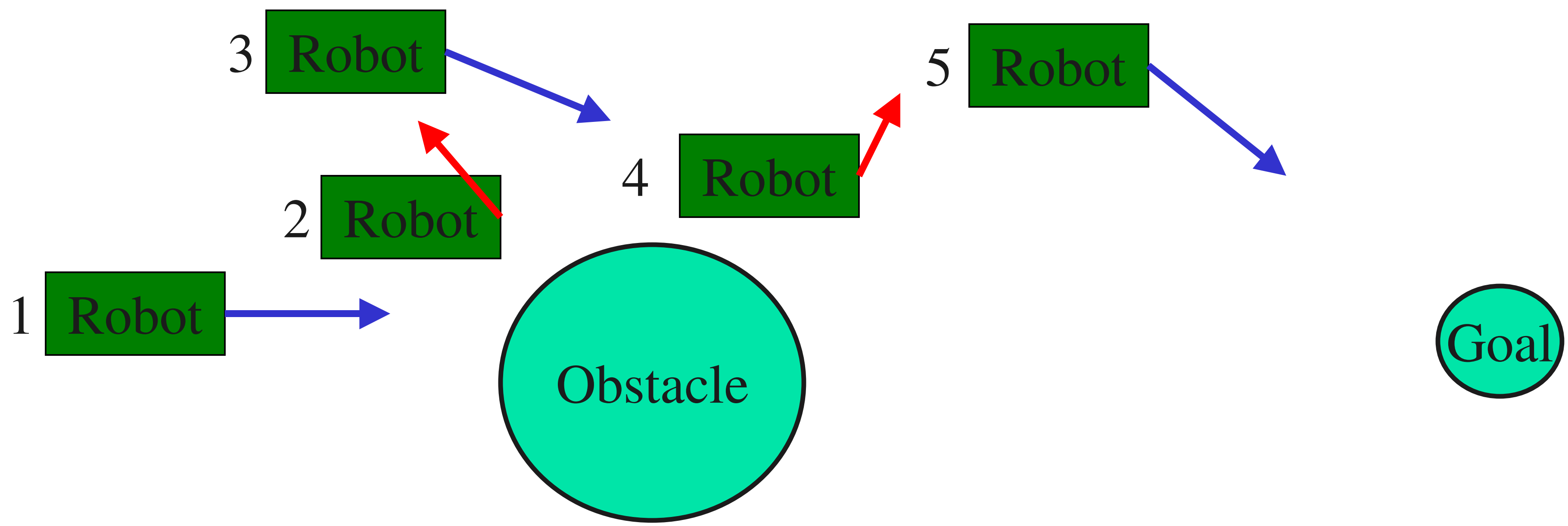


Goal vector

Avoidance vector

Resulting vector

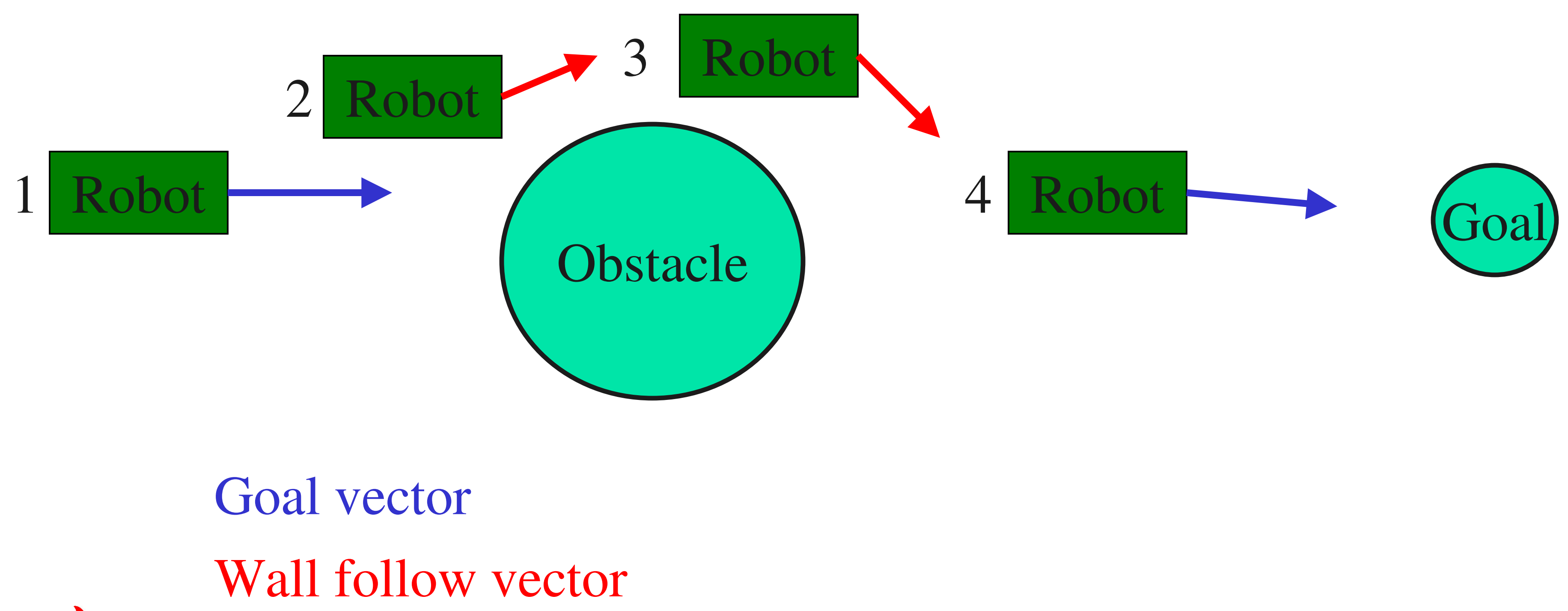
Competition



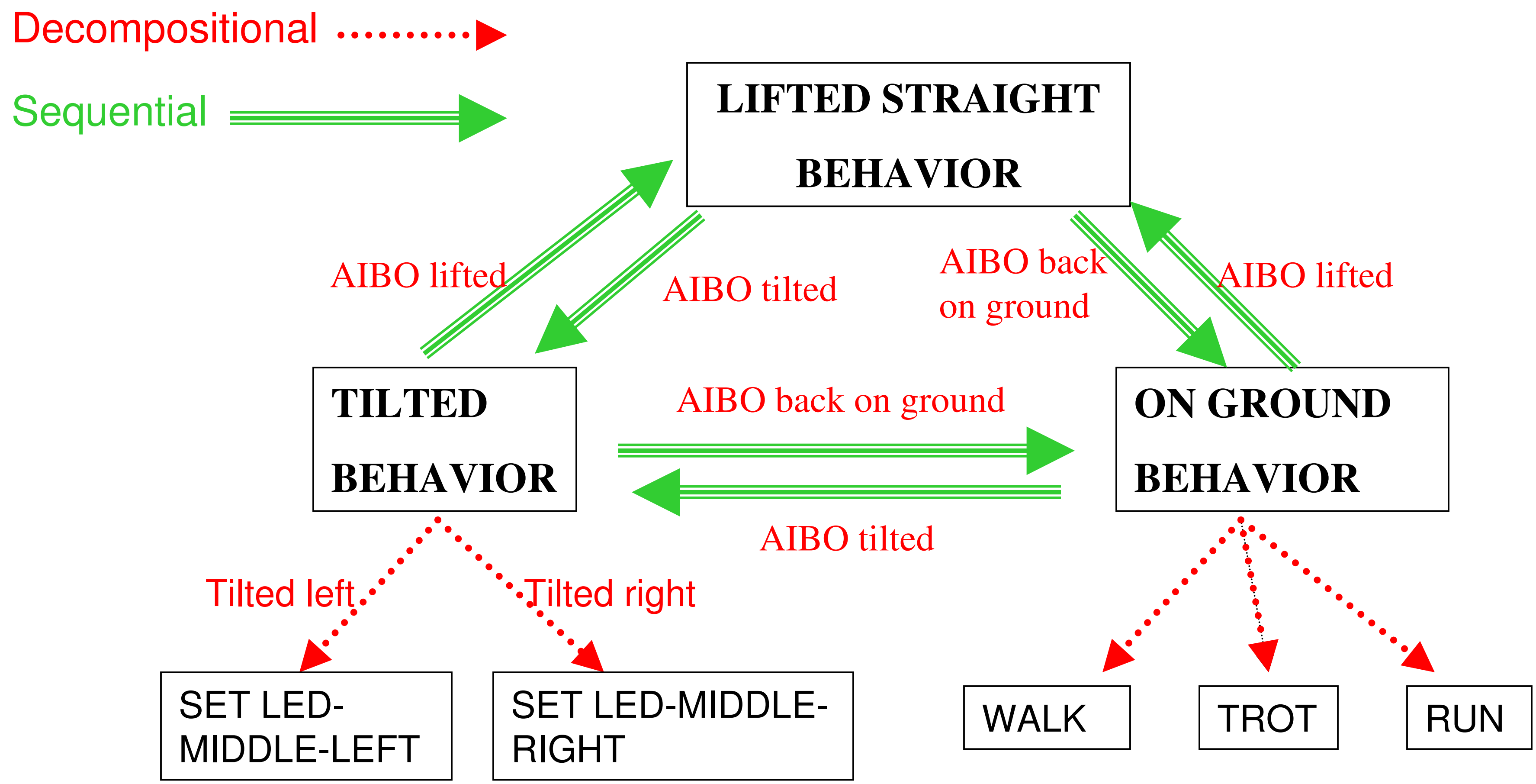
Goal vector

Avoidance vector

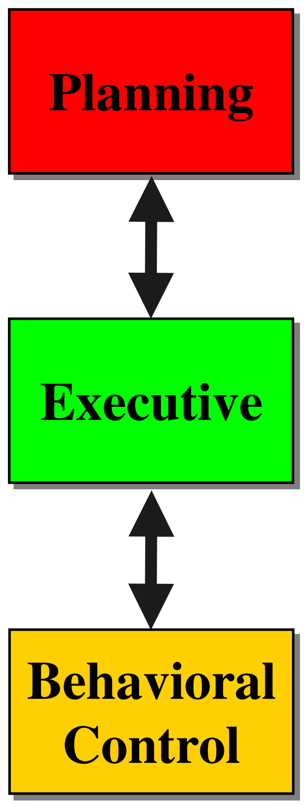
Subsumption



Example of Behavior/FSM



Three-Tiered Architectures



Deals with goals and resource interactions

Task decomposition; Task synchronization; Monitoring; Exception handling; Resource management

Deals with sensors and actuators

Path Planning

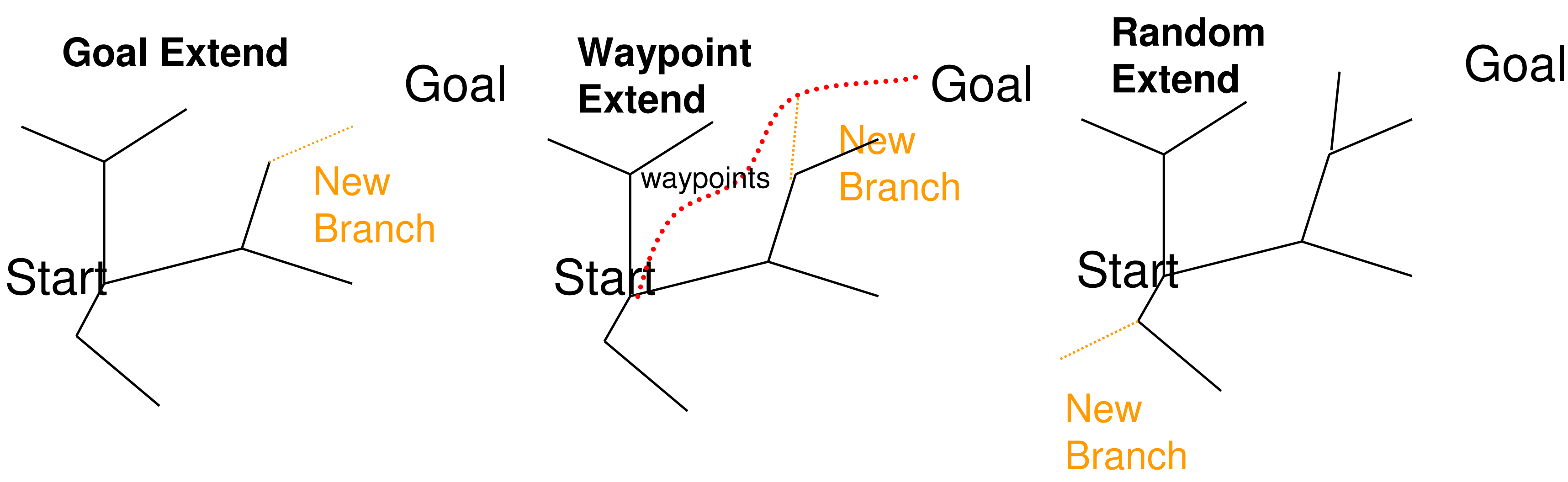
- Existence of a goal
  - *Goto* some goal point
- ERRT
  - Path planning
  - Smoothing
  - Memory

Replanning with Advice

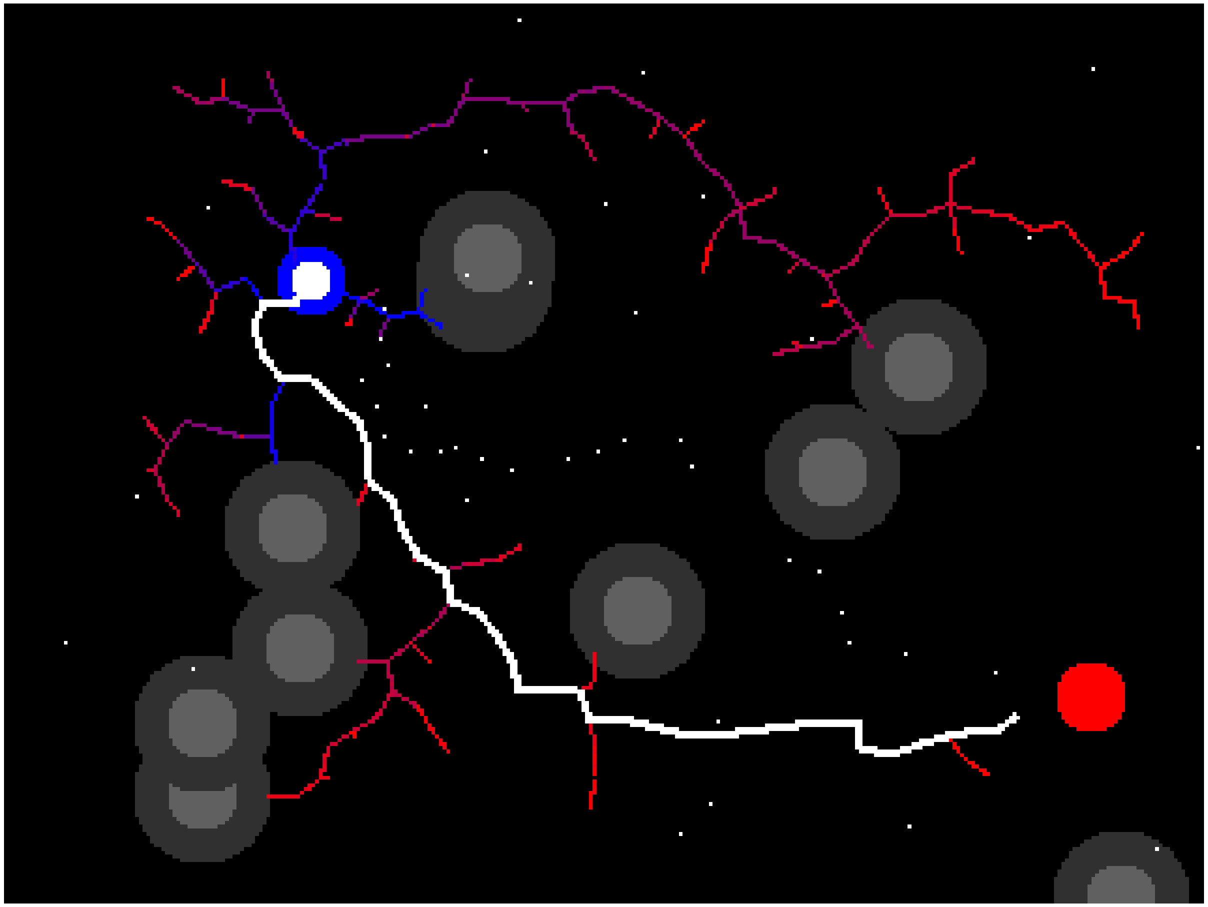
Probability *p* : Extend closest node in tree towards goal

Probability *r* : Extend closest node in tree towards random cache point

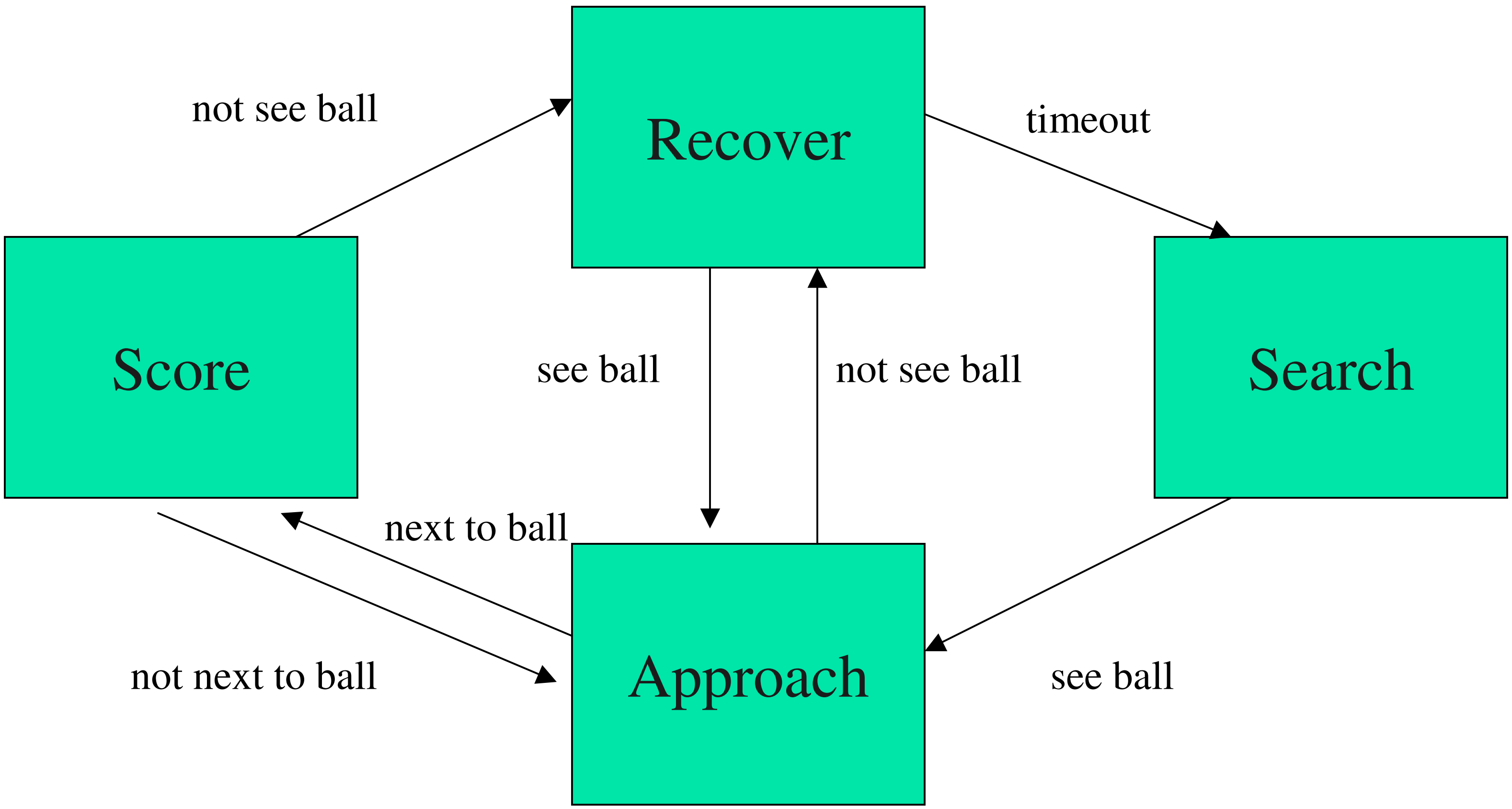
Probability *1-p-r* : Extend closest node towards a random point



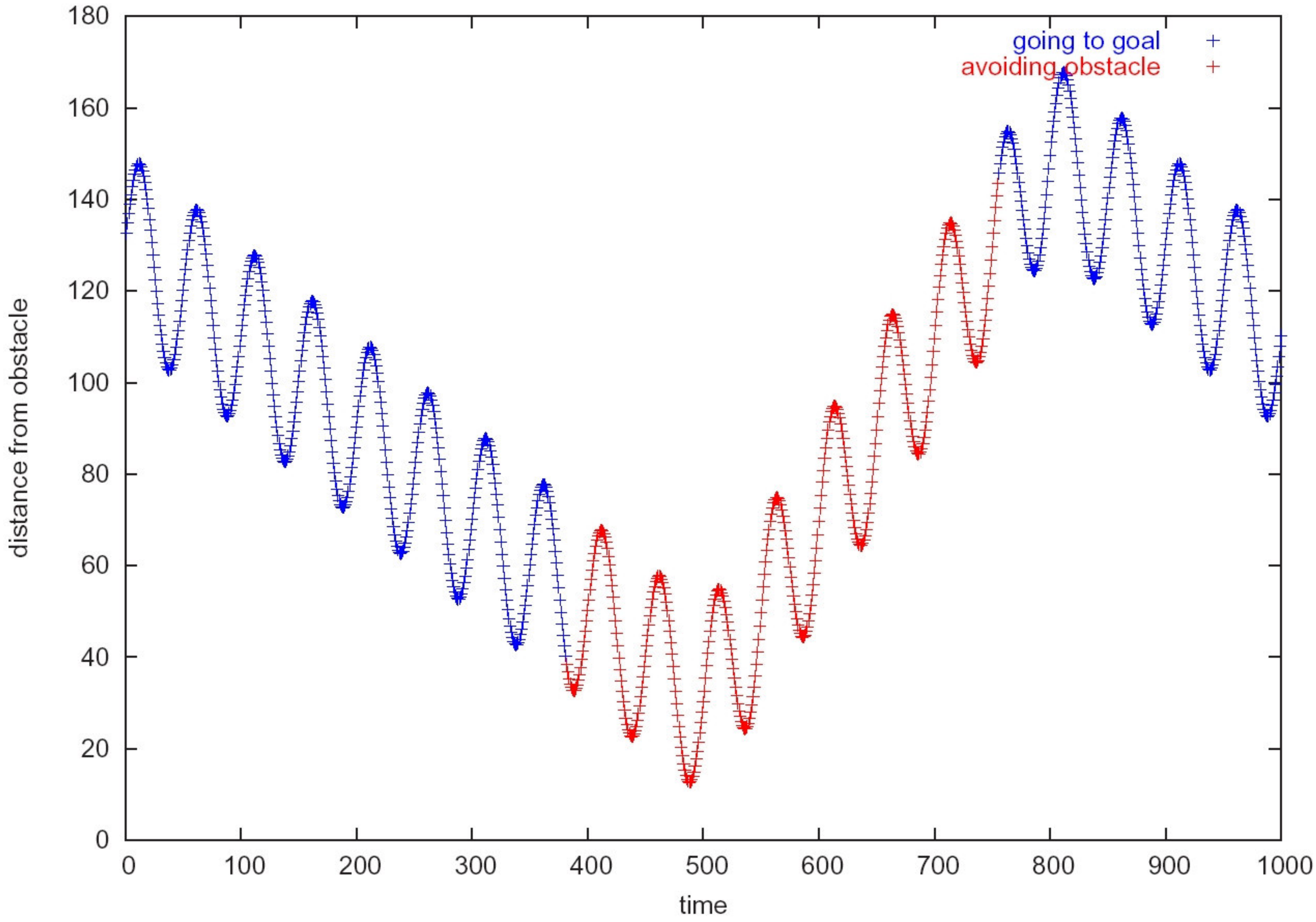
Path Planning and Replanning



Behaviors: FSMs

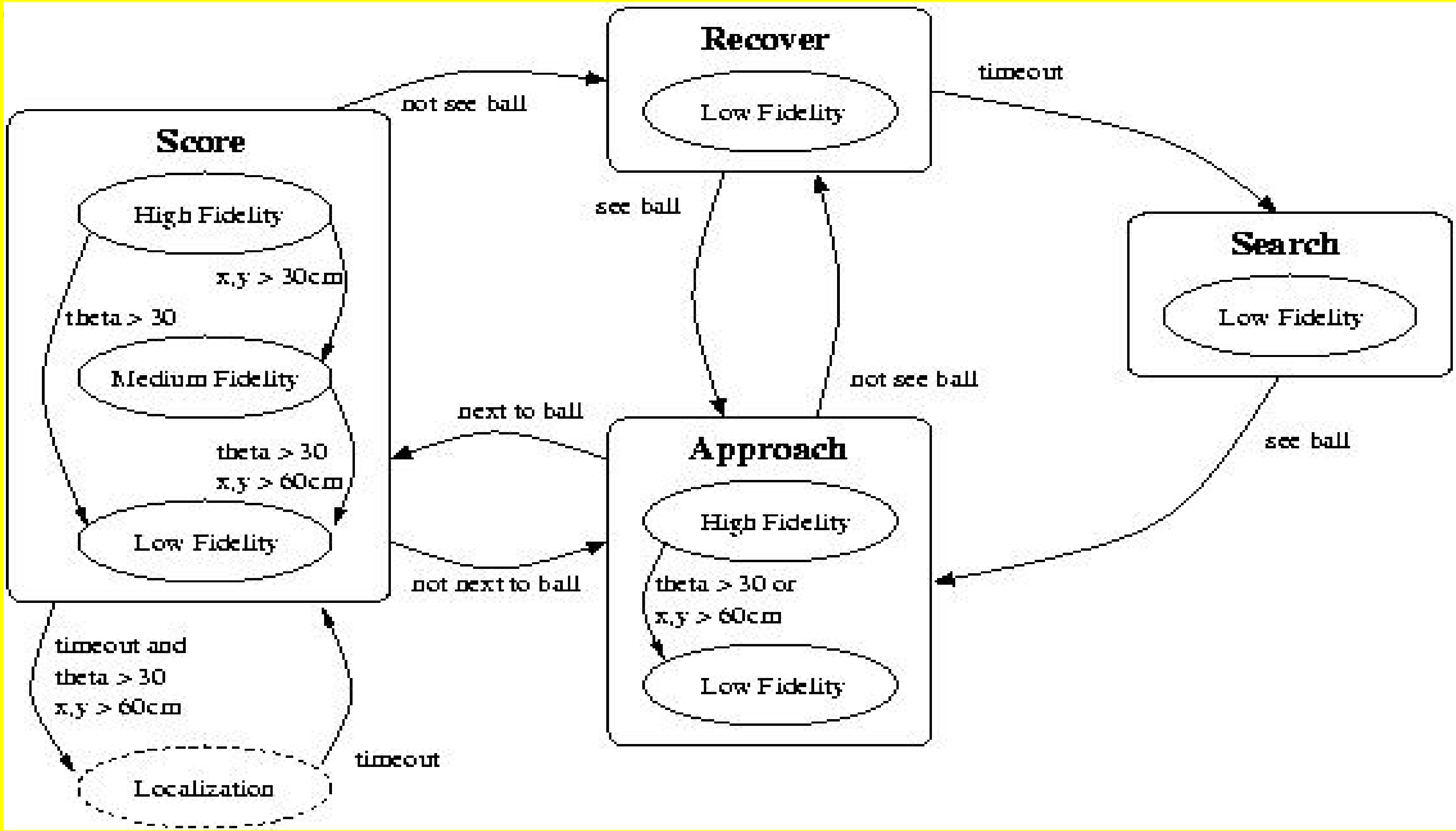


Hysteresis



going to goal
avoiding obstacle
distance from obstacle
time
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000

Handling Uncertainty



Hierarchy – Adding Scale

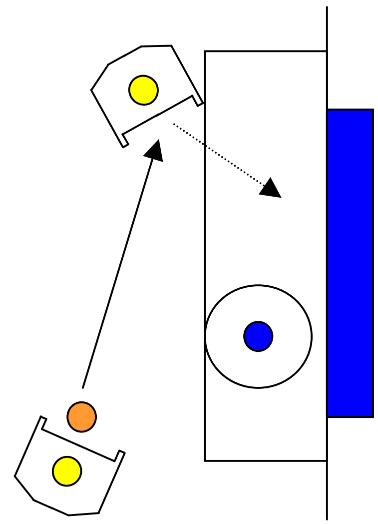
- In order to scale to large behaviors, we can reuse collections of lower-level behaviors
  - Libraries of lower-level behaviors form the building blocks for all AIBO behaviors
- Each state of FSM can be either a single reactive behavior, or another FSM with its own behaviors (or FSMs)

STP Behavior Architecture

- **Skills** – single robot low-level atomic behaviors
- **Tactics** – multi-skill combination for single robot goal achievement
- **Plays** – multi-robot coordination by planned sequence of tactics

Adaptive Playbook Strategy Engine

- Plays
  - A multi-robot plan represented as a temporal sequence of parameterized tactics
- Playbook language
  - Human understandable
  - Easy to add new plays like a real coach



Role 0
- Dribble to P_1
- Pass to R_2
- Wait for loose ball

Role 1
- Wait for Pass at P_2
- Receive Pass
- Shoot

Play Selection–Opponent Learning

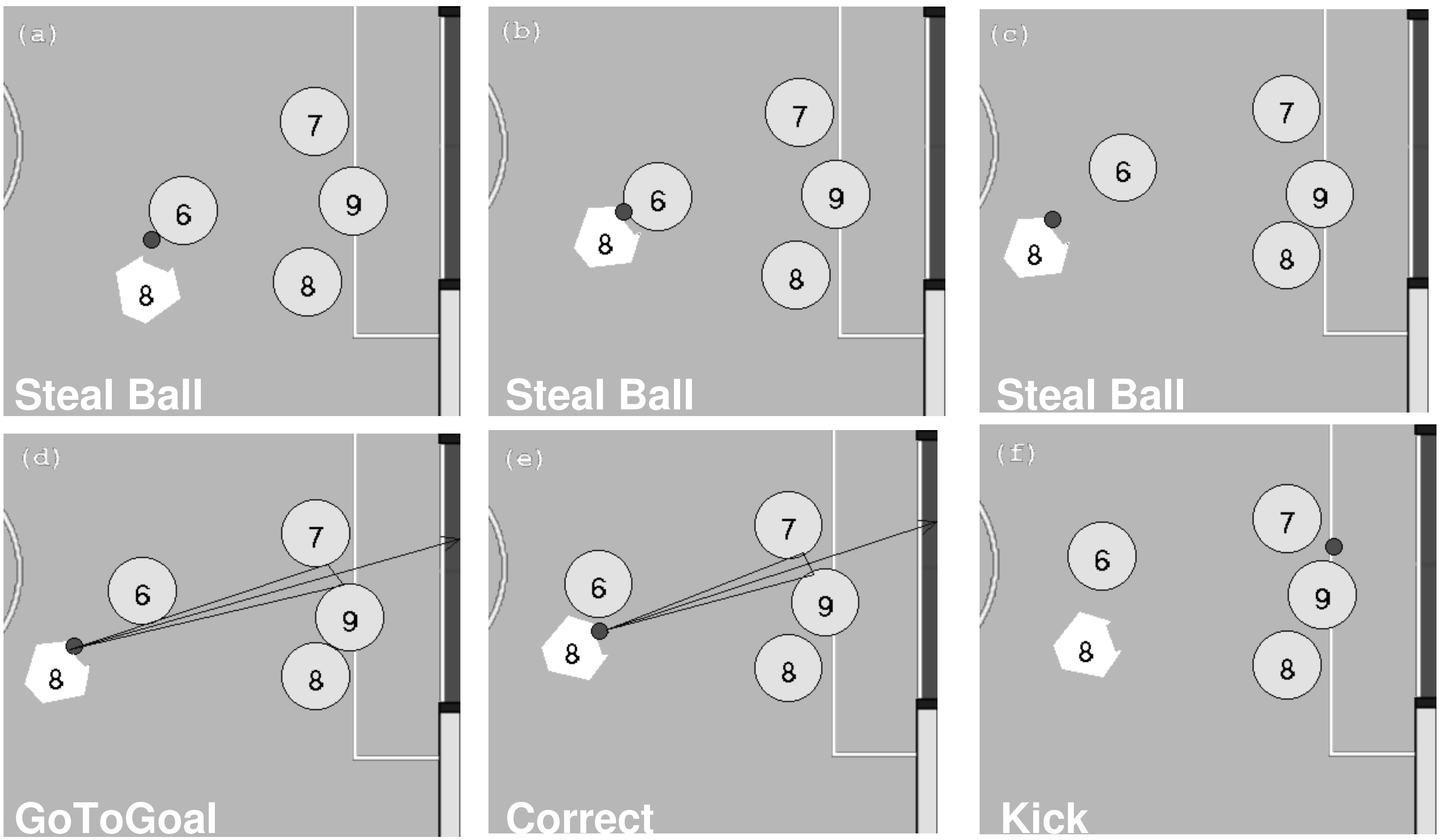
- Each play p_j has an associated weight w_j
- Stochastic play selection: from the set P_A of applicable plays with probability determined by w's

$$\mathrm{P}\left(p^* = p_j\right) = \frac{w_j}{\sum_{P_A} w_k}, \forall j \in P_A$$

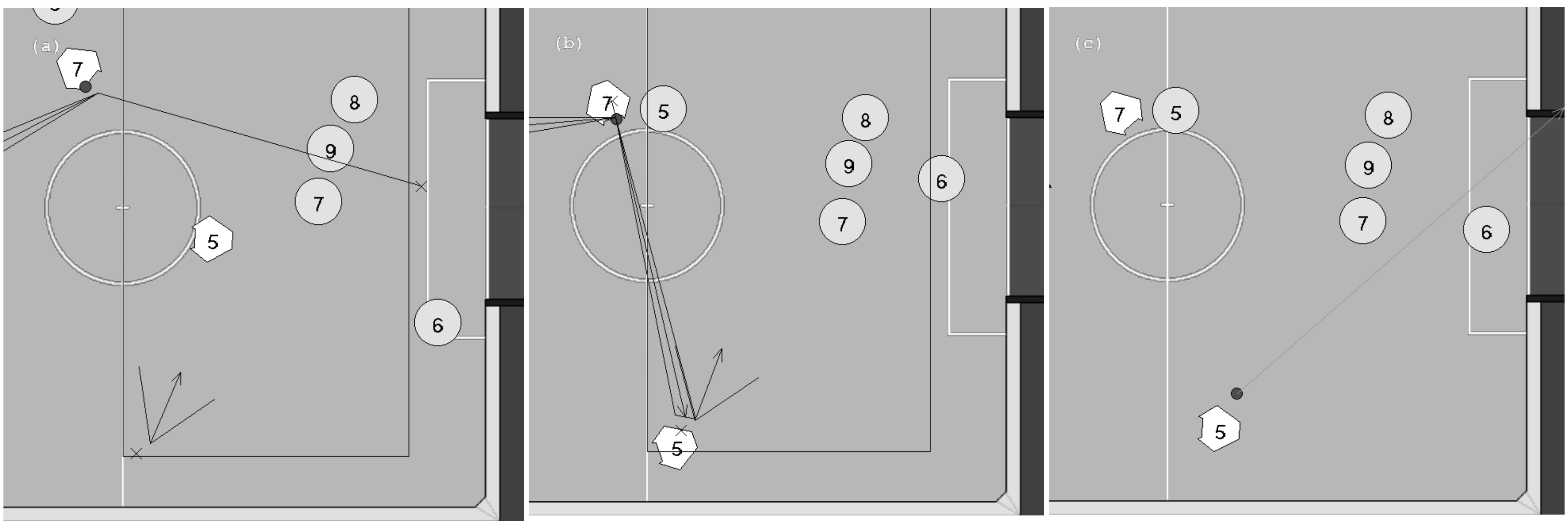
- ABORT, SUCCESS, FAILURE conditions
- Weights are adapted online – details later

Playbook adapts to the opponent without explicit modeling.

Replay Real Log – Tactic (< 1s)



Replay – Deflection Play (<1s)



Behaviors-II Conclusion

- Choice of behavior representation depends on conditions of the domain
- Ideally, planning ahead would be great
- Ideally, fast response to sensor changes

- Think well about which approach to take
- Homework: MasterMind.