Service Composition in Stochastic Settings

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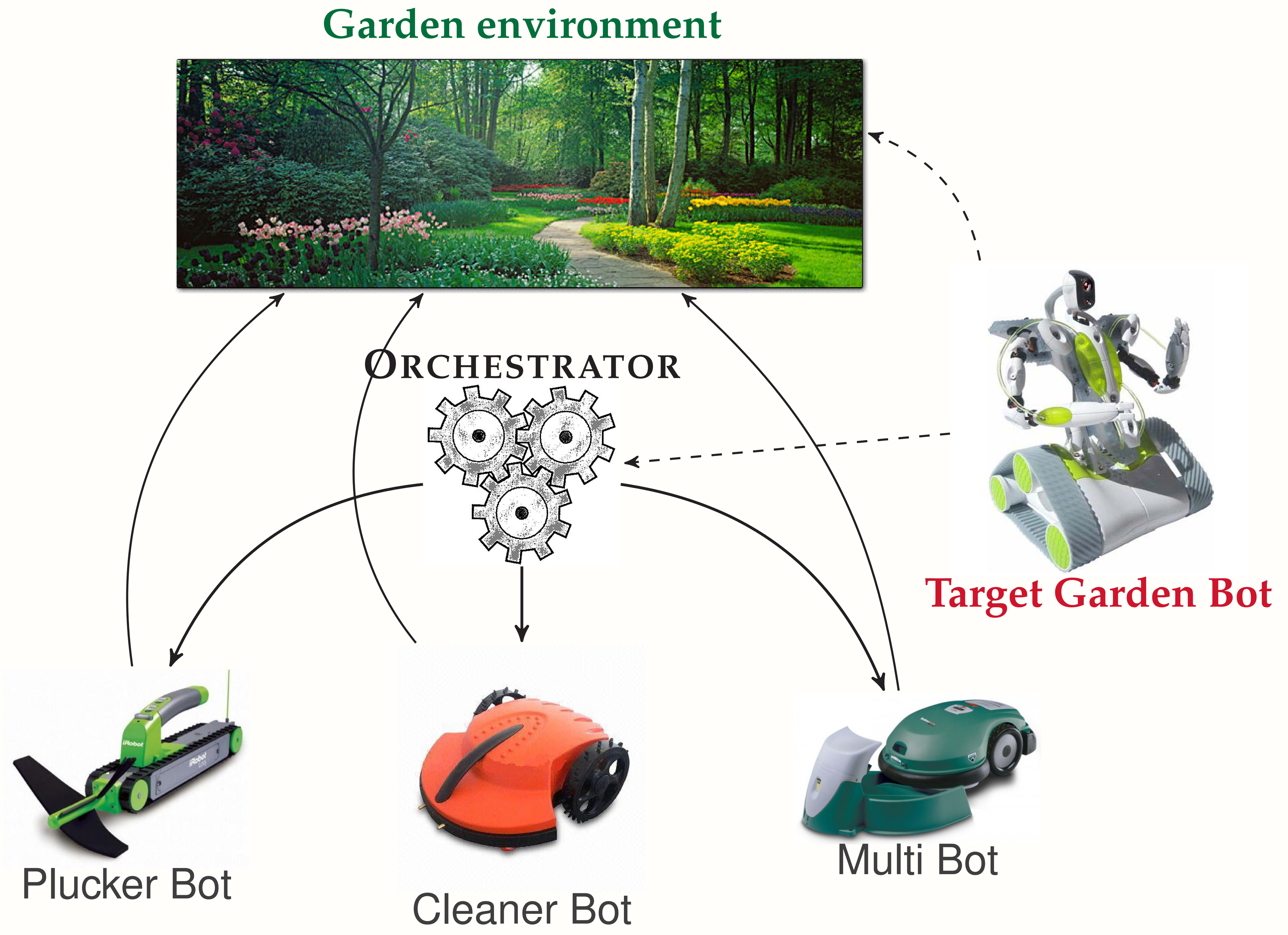
Service Composition



Task: Synthesize orchestrator that realizes virtual target service $\mathcal{T}$ by coordinating available services $\mathcal{B}_1 \ldots \mathcal{B}_n$ in environment $\mathcal{E}$.

- Available services: logic of machine, web service, etc.
- Environment: common ground for available services and target
- Target: desired virtual service.
- Orchestrator: delegates target actions to the available services

Motivations

Classical service composition approaches:

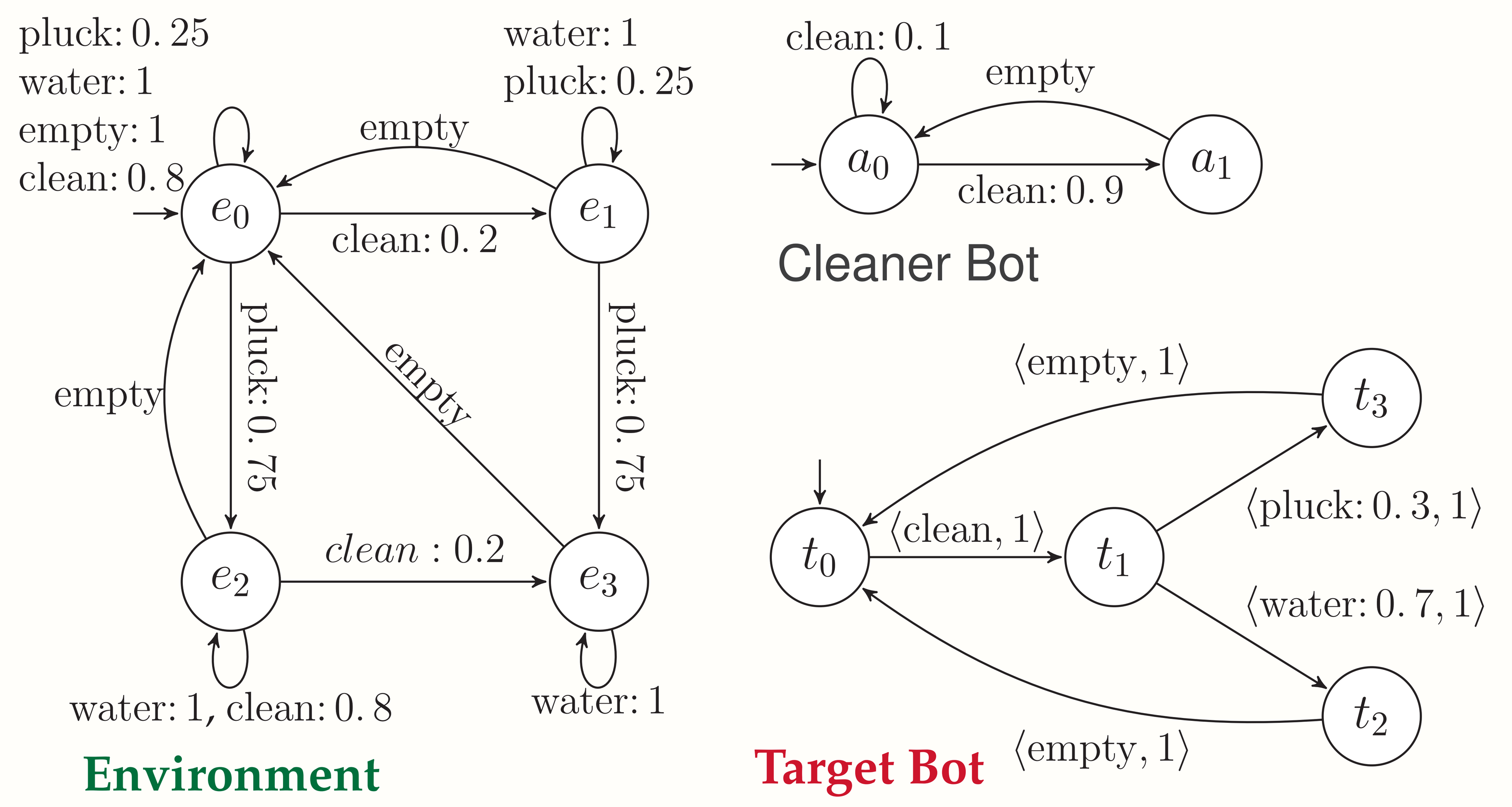
- Operate on deterministic and nondeterministic (devilish) settings
- Deal only with *exact* solutions

Objectives

Handle cases that do not admit exact solutions by:

1. Rewarding **actions in the target**
2. Allowing several sources of uncertainty:
   - **stochastic target**
   - stochastic environment
   - stochastic available services
3. Solving composition by MDP – basing optimality on target "expected realizability"

Stochastic Composition



- Reward for each action request
- Stochastic model for target action requests
- Stochastic transition evolutions in avail. services & environment

Orchestrator Evaluation

Value of orchestrator: Measures degree of target's **expected realizability**

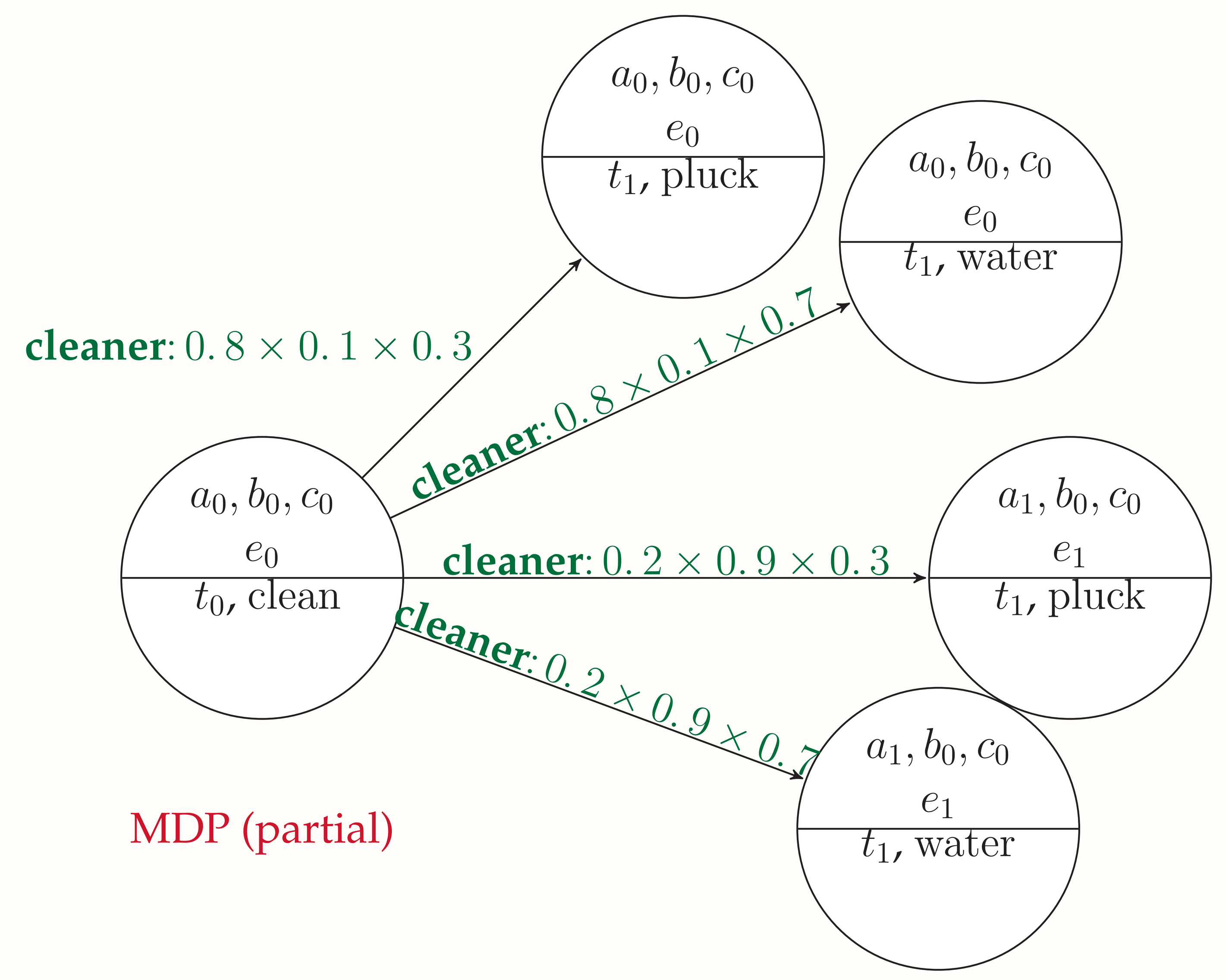
Rewards gained on:

- *successful action delegation:*
  Probability of action request × reward for the action request
- *one target step:*
  Reward R_i gained for each delegable target action request
- *on infinite runs:*
  $R_1 + \gamma R_2 + \gamma^2 R_2 + \ldots$, using discount factor $0 \leq \gamma < 1$

Results

If an exact orchestrator exists, then it is optimal

Reduction to MDP



Encoded into MDP $\mathcal{M} = \langle Q, A, p, r \rangle$:

- Q is the finite set of state encoding the states of the system, the state of the target, and the next requested action
- $A = \{1, \ldots, n\}$ is the set of available service indexes
- $p(q, i, q')$ is the stochastic transition relation encoding the possible next system state and action requested
- $r(q, i)$ is the reward allocated on **correct delegation** (0 otherwise)

Results

- Optimal policy for $\mathcal{M} \equiv$ optimal orchestrator
- Existence of exact orchestrator can be checked by calculating optimal policy of MDP

Extensions

- *Handling exceptions*: undo actions!
- *Separate rewards specification*: composition is a notable example
- *Non-Markovian rewards* expressed in LTL_f or LDL_f or through programs, e.g., for:
  - *extended constraints*, e.g., action empty must be suitable only after action pluck has been executed
  - *preferences*, e.g., in certain conditions Plucker-bot uses less energy than the Multi-bot
- *Reinforcement learning*: learn probabilities and rewards online