A Formal Metareasoning Model of Concurrent Planning and Execution

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Setting: Situated Planning

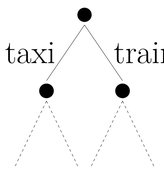
classical planning: **s**tatic world
batch planning: plan then execute

situated planning: **t**ime passes during planning

- need plan that is feasible when it is found
- previous work: situated but still batch
- **t**his work: concurrent planning and execution
- assume planning as forward heuristic search
- objective: maximize probability of timely plan

Challenges

Search nodes can **e**xpire:
deadlines, exogenous events



which node to expand?

- required search time uncertain
- expiration time uncertain until plan is complete
- trade-off: later deadline vs shorter search time

acting under uncertainty
even though actions are deterministic!

Previous Work on Batch Case

formal metareasoning model $(AE)^2$ (AAAI-19)

- given: beliefs over deadlines, planning time
- actions: **a**llocate planning time under nodes
- objective: maximize probability of finding timely plan
- simplified version $\rightarrow$ MDP
- NP-hard but tractable special cases

greedy algorithms (ICAPS, 2021)

- improves situated planning!

Example

plan to take train to airport

- departs in **6 min**, takes **22 min**, then either
- a) no transfer necessary (**0 min**, $p = 0.8$) or
- b) shuttle bus (**10 min**, $p = 0.2$)
- est. further planning time: **8 min** ($p = 1.0$)

plan to take taxi to airport

- call taxi (**2 min**), ride (**20 min**), then either
- a) payment **1 min** ($p = 0.5$) or
- b) payment **10 min** ($p = 0.5$)
- est. further planning time: **4** ($p = 0.5$) or **8** ($p = 0.5$)

Allocating search time equally fails
(even $8 + 2 + 20 + 1 > 30$)
Optimal $(AE)^2$ policy: search under taxi, hope for fast planning and payment ($p_{success} = 0.25$)

needs metareasoning!

Concurrent Execution

CoPE extend $(AE)^2$ metareasoning model

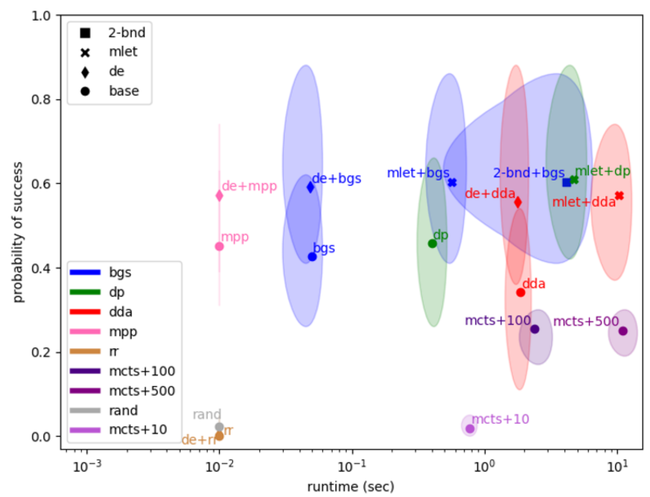
- additional action: **d**ispatch a base-level action
- clearly NP-hard but tractable special cases

greedy algorithms: extend any $(AE)^2$ alg A

- 'maximize success using latest execution time' (Max-LET$_A$)
- 'demand execution' (DE$_A$)

Optimal CoPE policy: search under taxi for 4 min. If finds fast payment plan, then execute, else take train and search under train.
CoPE achieves $p_{success} = 0.85 > 0.25$

Experiments



Max-LET$_{BGS}$ better, DE$_{BGS}$ faster

Conclusions

CoPE: a formal model of concurrent planning and execution

- clarifies issues in situated planning
- removes last major assumption of classical planning
- situated search requires metareasoning
- metareasoning as decision-making under uncertainty
- weigh risk of acting vs planning

Greedy algorithms

- several seem practical
- next step: a situated planner/executive

Metareasoning pays off when planning under time pressure!

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