CAMP-BDI: A Pre-emptive Approach for Plan Execution Robustness in Multiagent Systems

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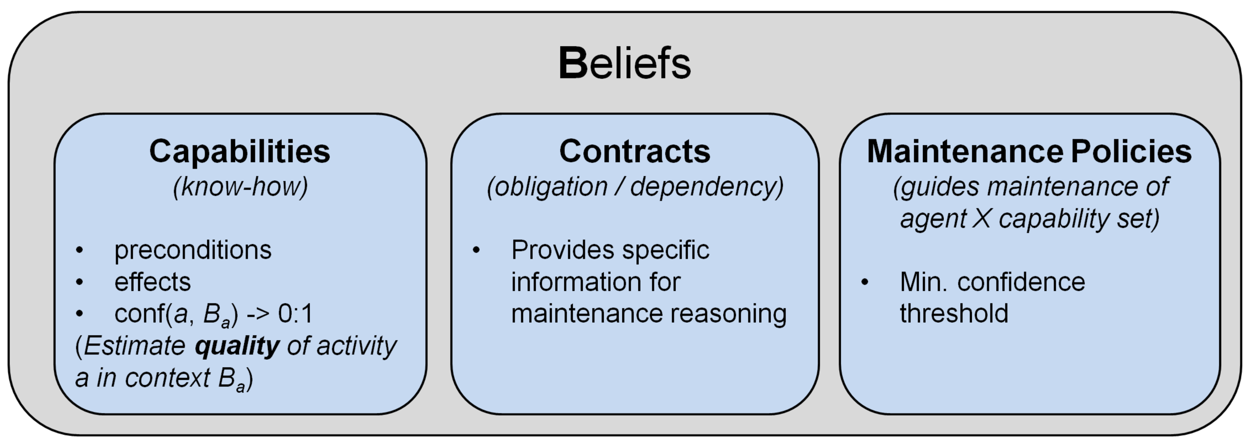
Introduction

Failure mitigation during plan execution an important component in BDI agent robustness. In realistic environments exogenous change may increase likelihood of activity failure, threatening intended plans and associated goals. **Failure itself may incur debilitative consequences or costs**, hindering typical reactive recovery and potentially threatening future goals. **We argue *proactive* failure mitigation may be beneficial in realistic environments** by preventing failure-associated debilitation.

We contribute the CAMP-BDI approach (**C**apability **A**ware, **M**aintaining **P**lans) – embodying BDI agents with know-how to **introspectively reason** about intended plans, plus algorithms to **identify threats** caused by exogenous change and pre-emptively **modify (maintain) plans in response**.

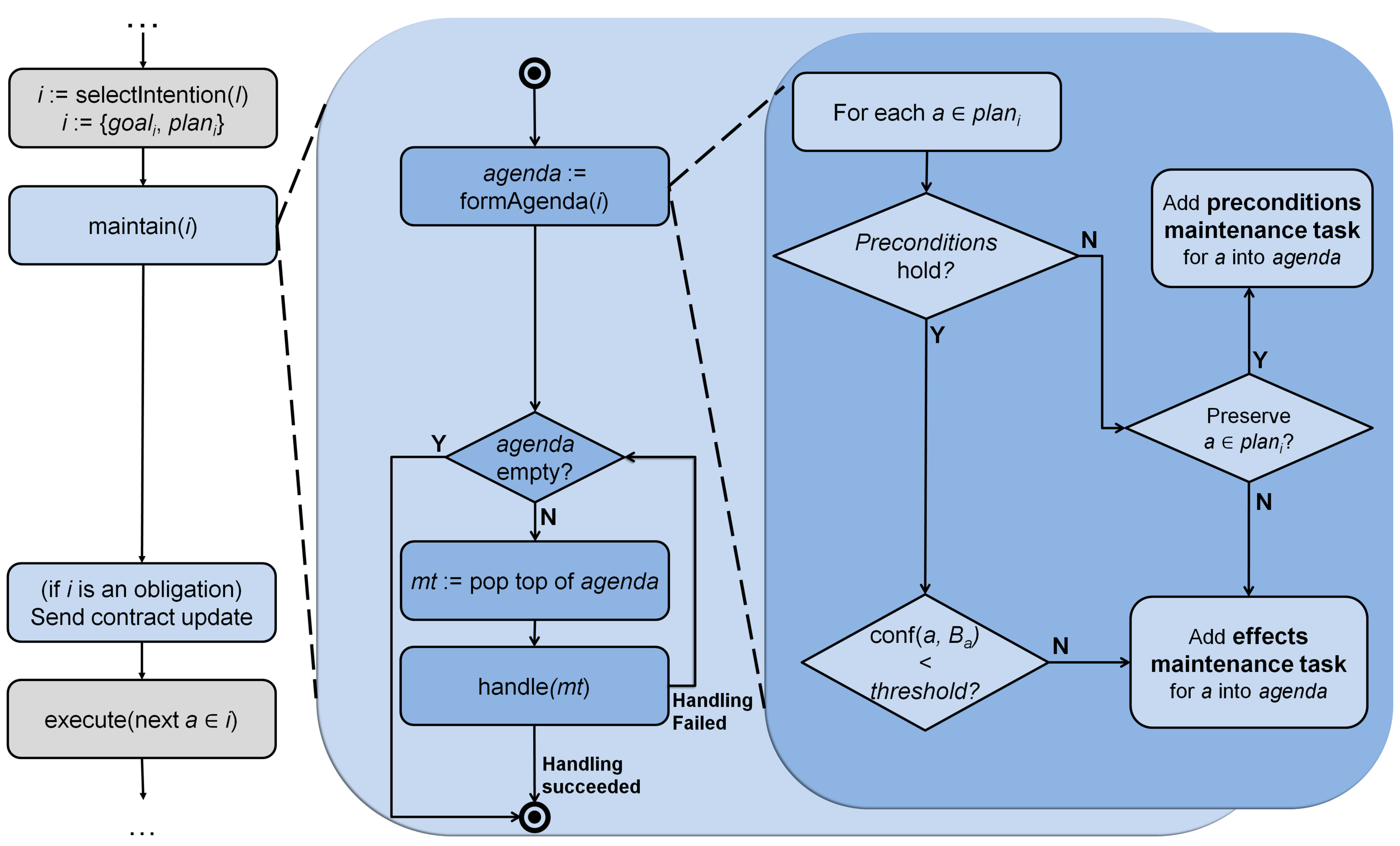
The CAMP-BDI Supporting Architecture

CAMP-BDI agents are equipped with meta-knowledge to support maintenance, representing an extension of agent **Beliefs**;



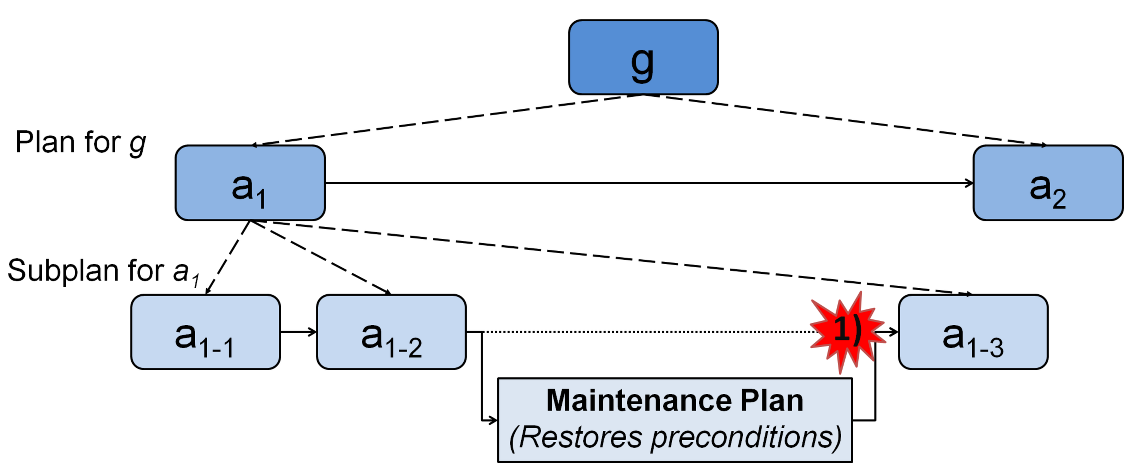
The CAMP-BDI Reasoning Cycle

Extends BDI reasoning cycle to identify and handle threats to planned activity;



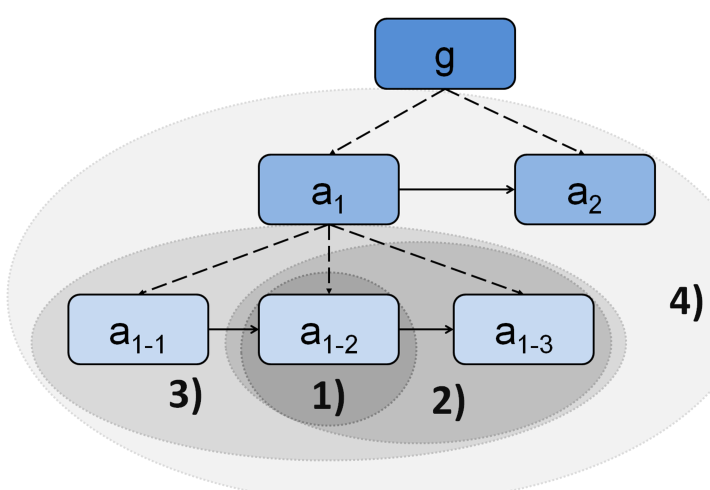
Handling a Preconditions Task

E.g. Find and insert $plan_M$ **to re-establish** a_{1-3}**'s violated (1) preconditions**;



Handling an Effects Task

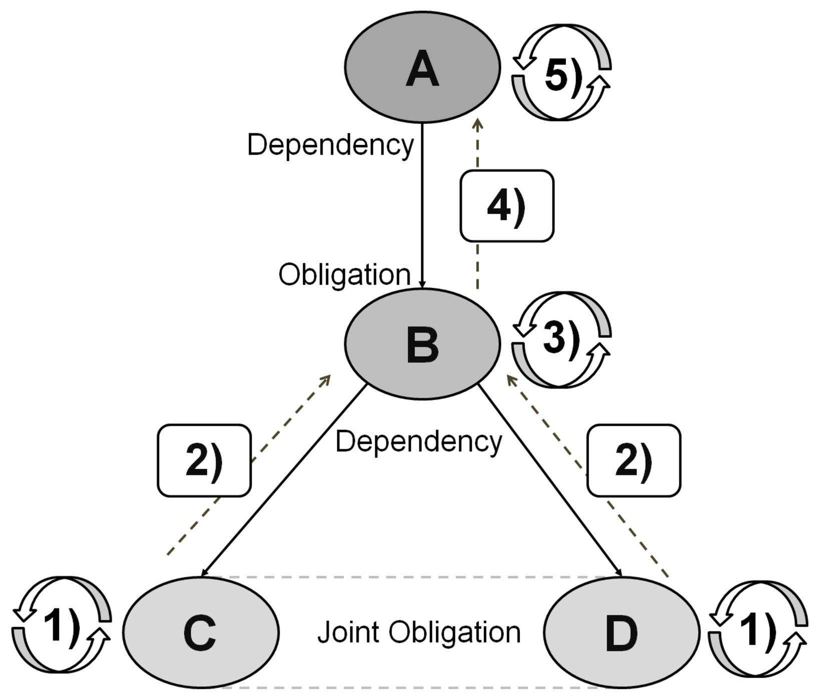
Handling a task for a_{1-2} entails **replacing some subset of the intended plan** inclusive of a_{1-2}, with a $plan_M$ **achieving equivalent *effects***;



1) Form $plan_M$ to directly replace a_{1-2}, achieving the same effects
2) Insert an $plan_M$ to replace a_{1-2} and following actions inclusive
3) Insert an $plan_M$ to re-refine parent subgoal a_1
4) Iteratively expand scope up the plan hierarchy until $plan_M$is inserted, or root goal g reached reached without success.

Distributed Maintenance

Decentralized approach based upon **post-maintenance messaging** to update contract information. Dependants decide whether to **adopt responsibility** and maintain a dependant $plan_i$ upon receipt.



1) Obligants **C** & **D** maintain
2) C, **D** independently send dependant **B** post-maintenance contract updates
3) B maintains the dependant intention – itself an obligation to **A**
4) B sends a post-maintenance update to **A**
5) A performs maintenance of it's local dependant intention, using received information

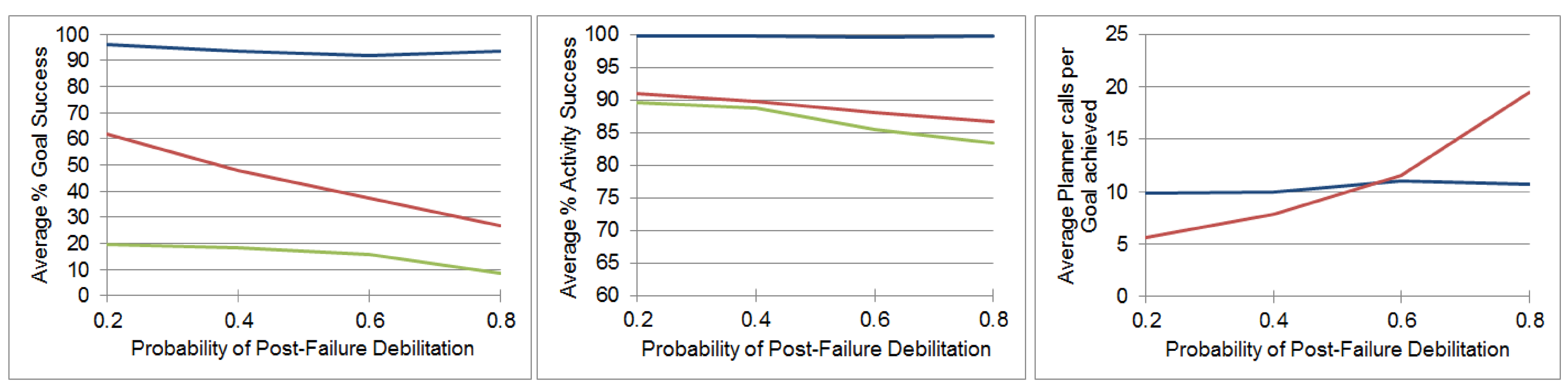
Iterative adoption of maintenance responsibility up the dependency hierarchy mimics local plan maintenance process across a distributed intended plan.

Evaluation

We compared a **CAMP-BDI** multiagent system against one employing **Reactive** re-planning; a system with **No-failure mitigation** gave a worst case baseline.

A **Logistics** environment, requiring distributed plan execution by teams of heterogeneous agents, was employed for evaluation. Various **exogenous changes** could threaten activities; **landslips**, road **flooding** or **locations becoming dangerous**.

Results averaged for **10 runs** of 100 cargo deliveries, **for probabilities 0.2→0.8** of post-failure debilitation (agent or cargo damage, or cargo spillage contamination)



CAMP-BDI shows relative consistency of performance due to avoidance of failure consequences in the continuous environment. **Reactive approach worsens as post-failure debilitation becomes more likely**, with planning cost increasingly high as failure results in intractable recovery.

Conclusions

- CAMP-BDI agents employ a **Proactive failure prevention** using supporting architecture knowledge and maintenance algorithms to prevent failure through plan modification.
- This offers **utility** in environments **where failure risks debilitative consequences** and capability knowledge can be used to evaluate planned future activity quality.
- We suggest CAMP-BDI offers a **complimentary approach to reactivity**, rather than a replacement – failure will always be inevitable in realistic environments.
- Further work will examine **cost**, particularly for domain analysis, use of maintenance **policies to target maintenance** behaviour, and general **optimisation**.

Acknowledgements

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