Simple Temporal Problems for Improvisational Teamwork

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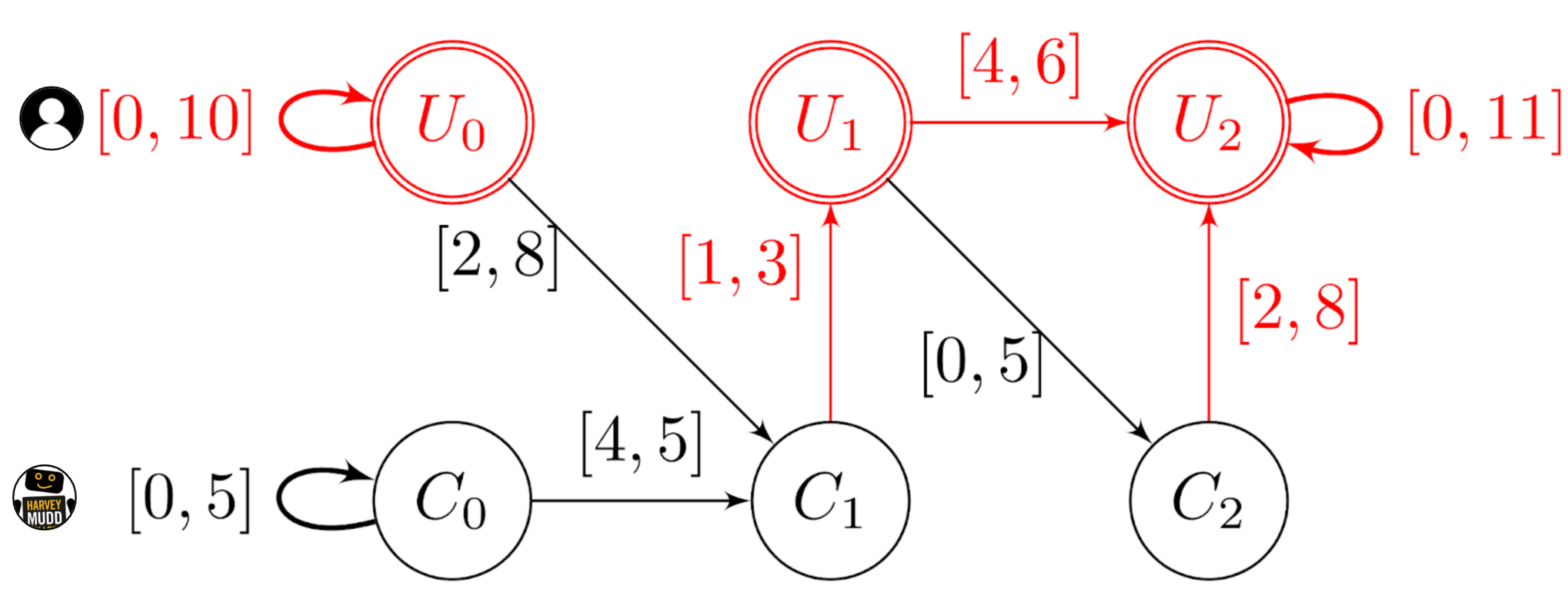
Goal

A strongly controllable execution strategy for Multiagent Simple Temporal Networks (MaSTN) that controls for how a teammate will act in situations when communication between agents is not possible.

Simple Temporal Network for Improvisational Teamwork (STN-IT)



STNs for Improvisational Teamwork (STN-IT) are Multiagent STNs where the set of agents is partitioned between a set of controllable agents (e.g., a robot; top, red) and uncontrollable agents (e.g., a human teammate; bottom, black). Unlike STNs with Uncertainty (STNUs), our formulation does *not* designate specific edges or events as contingent or uncontrollable, but which type of agent is responsible for them. Additionally, we assume:

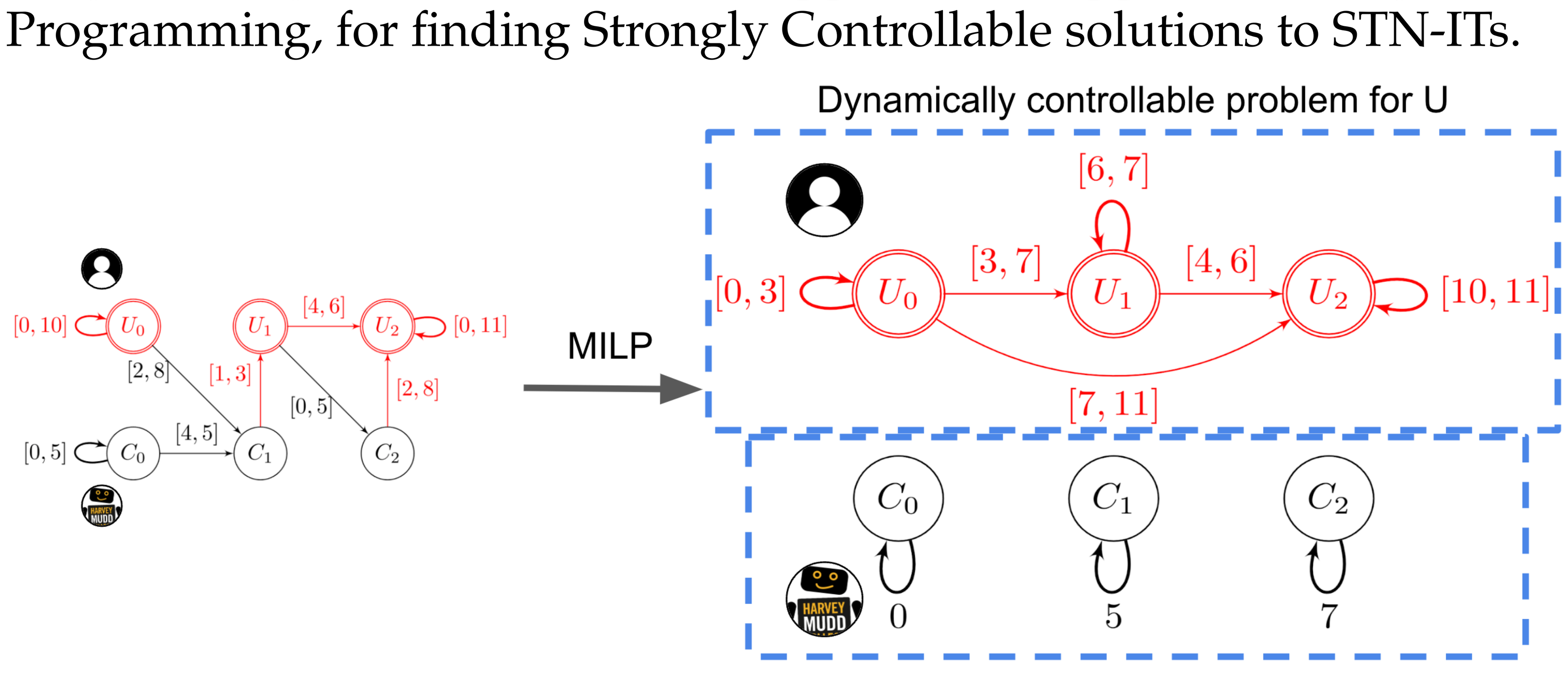
1. **Problem Observability:** Agents can observe and reason about the global STN-IT.
2. **Event Observability:** Agents can observe when all events occur as they are executed.
3. **Execution Consistency:** Agents will choose an execution strategy that is consistent with all problem constraints and event observations once they occur. The uncertainty is thus over possible temporal plans, and not the space of all possible executions.

STN-IT Strong Controllability

We formally define an STN-IT to be *strongly controllable* if we can assign specific times to the controllable timepoints in a way that is guaranteed to work with any consistent, dynamically determined realization of uncontrollable timepoints.

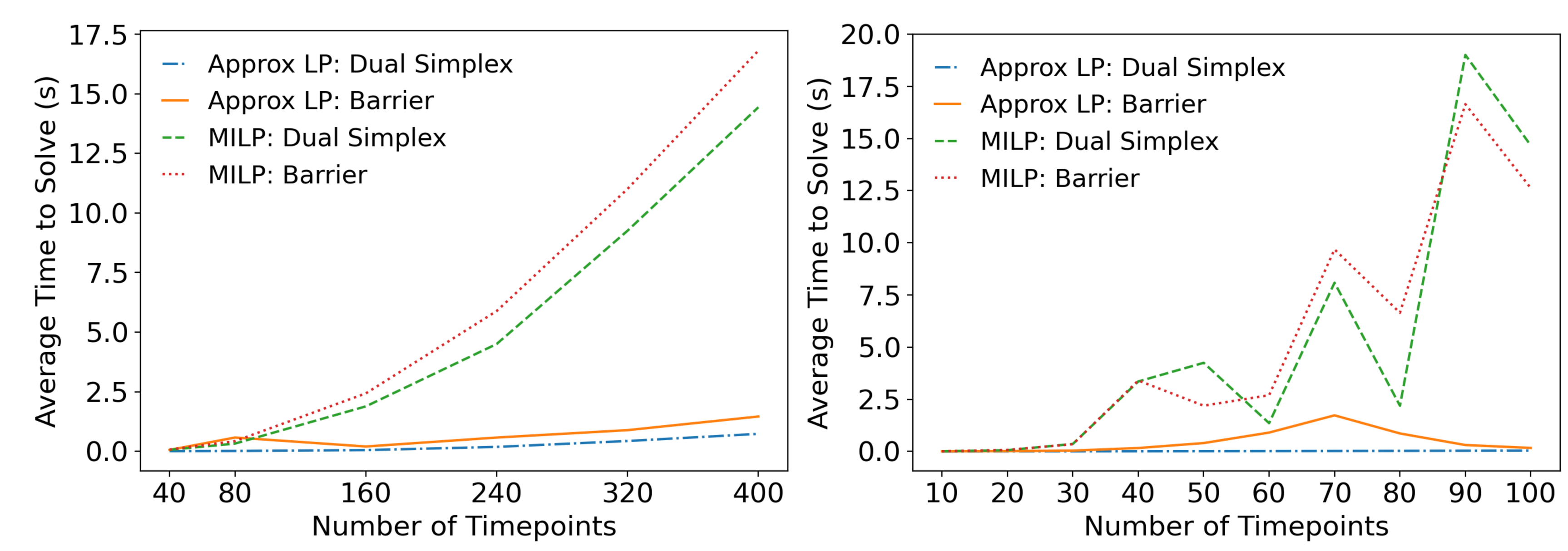
Approach Overview

Our paper presents both an exact approach, using Mixed Integer Linear Programming (shown below), and approximate approach, using Linear Programming, for finding Strongly Controllable solutions to STN-ITs.



Runtime Efficiency

We evaluate our MILP and Approximate LP on an existing benchmark of MaSTN problems [1] that we converted to STN-ITs (left). We also generated additional, more interesting STN-IT instances that require greater coordination and are more difficult to resolve by adapting the same MaSTN benchmark generator [1] (right).



Accuracy

Out of our new benchmark of 1000 STN-ITs, our MILP approach found strongly controllable solutions for 634 instances, which we empirically verified as correct. Our Approximate LP approach always produced a solution, but only 286 were fully strongly controllable.

Control Method	Number of solutions	Number of failures	Number of timeouts	Empirically Verified
MILP	634	355	11	634
LP	1000	0	0	286

We also simulated an uncontrollable agent that chose execution times randomly (left) or as early as possible (right). We report the portion of executions that succeed across *all* problems and just the *strongly controllable (SC)* ones. Thus, in practice, our Approximate LP resulted in successful execution in the majority of cases that the MILP succeeded.

Control	Random Unctrl.		Early Unctrl.	
Method	All	SC	All	SC
MILP	63.4%	100%	63.4%	100%
LP	56.52%	69.6%	52.8%	62.0%

Conclusions

- Our new framework of an STN for Improvisational Teamwork models impromptu teamwork that lacks reliable communication.
- We define strong controllability for STN-ITs and provide an exact solution method using Mixed Integer Linear Programming, which we verify its correct both analytically and empirically.
- We also provide an approximate solution method using Linear Programming, which we show that it scales much more efficiently, but moderately sacrifices the accuracy of the solutions.

References

[1] J. Boerkoel and E. Durfee. Distributed reasoning for multiagent simple temporal problems. *Journal of Artificial Intelligence Research*, 47:95–156, May 2013.

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