Efficient Monte-Carlo Tree Search in Deterministic Environments

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Amplifying exploration in MCTS by focusing on the unknown boosts performance through better coverage of the search space.

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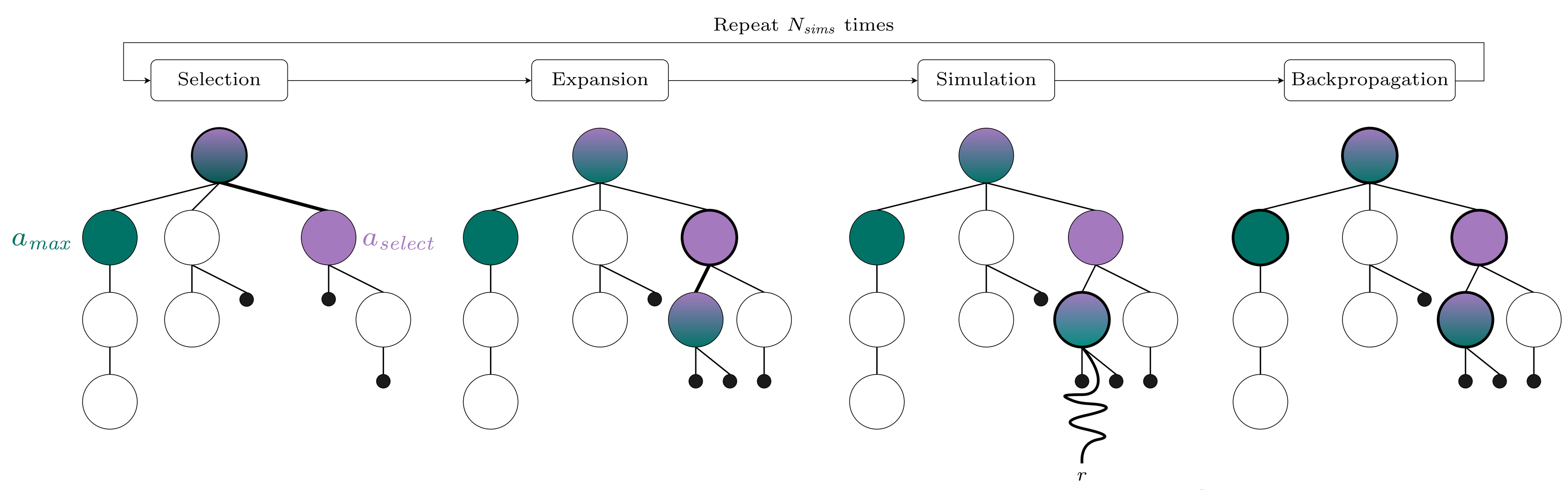
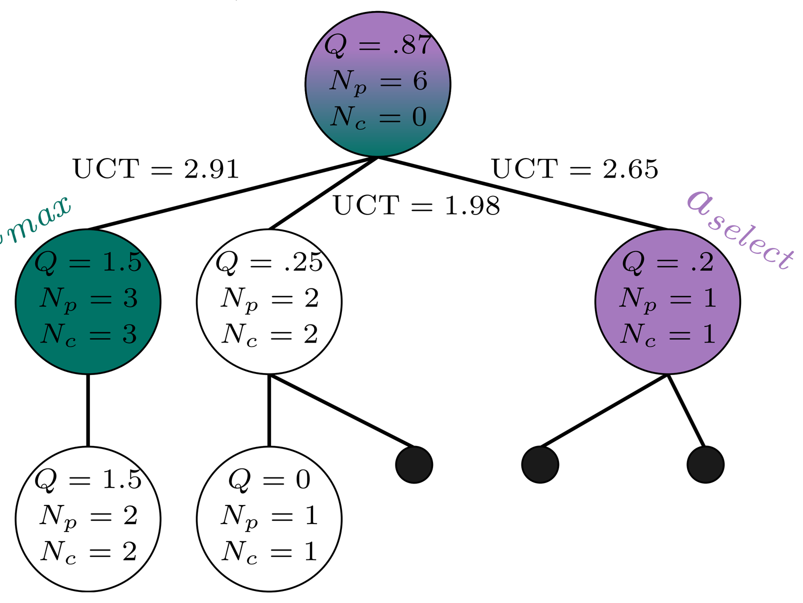
Idea

- **Classical MCTS is very inefficient in deterministic problems**. It wastes a lot of computational resources on known parts.
- We **exclude completely explored areas of the search space** and instead **focus on exploring the unkown parts** in order to find better solutions where classical MCTS doesn't look.
- Intergral of our method is the **decoupling of value updates, visit count increments, and path selection**.

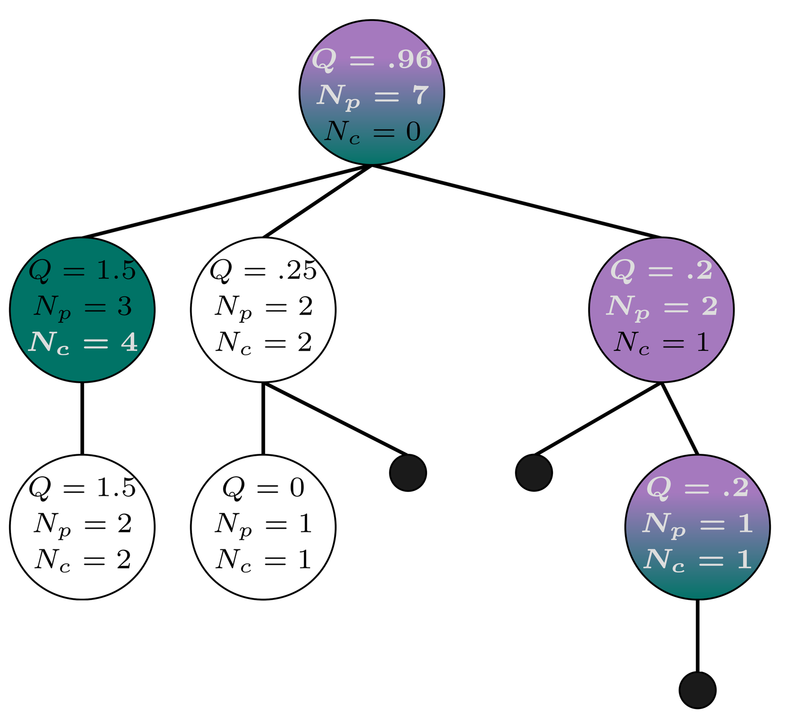
Amplified Exploration MCTS



- **Selection:** Differentiate between highest UCT score (a_{max}) and highest UCT score among the actions that are not completely explored (a_{select}) to only explore new paths where we can gain new information. $\mathrm{UCT} = Q + C \cdot \sqrt{\frac{\ln(N_p)}{N_c}}$



- **Expansion:** A transposition table is used to avoid redundancy. In the case of a known state, the stored values are directly backpropagated.
- **Simulation:** The simulation phase remains unchanged.
- **Backpropagation:** a_{max} and a_{select} are updated differently to ensure accurate statistics for future exploration while avoiding redundant information from completely explored subtrees. Nodes with only completely explored children are marked completely explored as well.

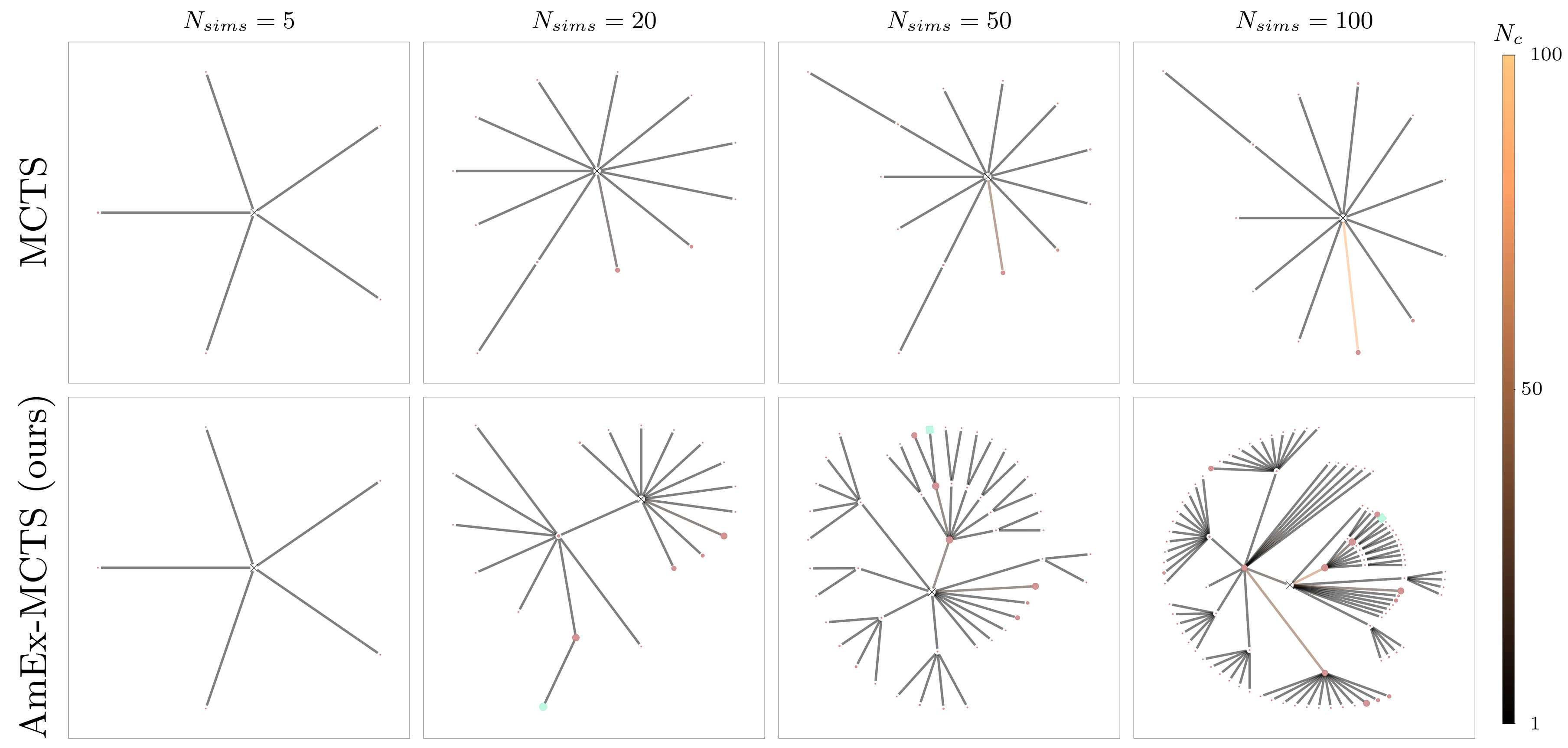


Theoretical Guarantees

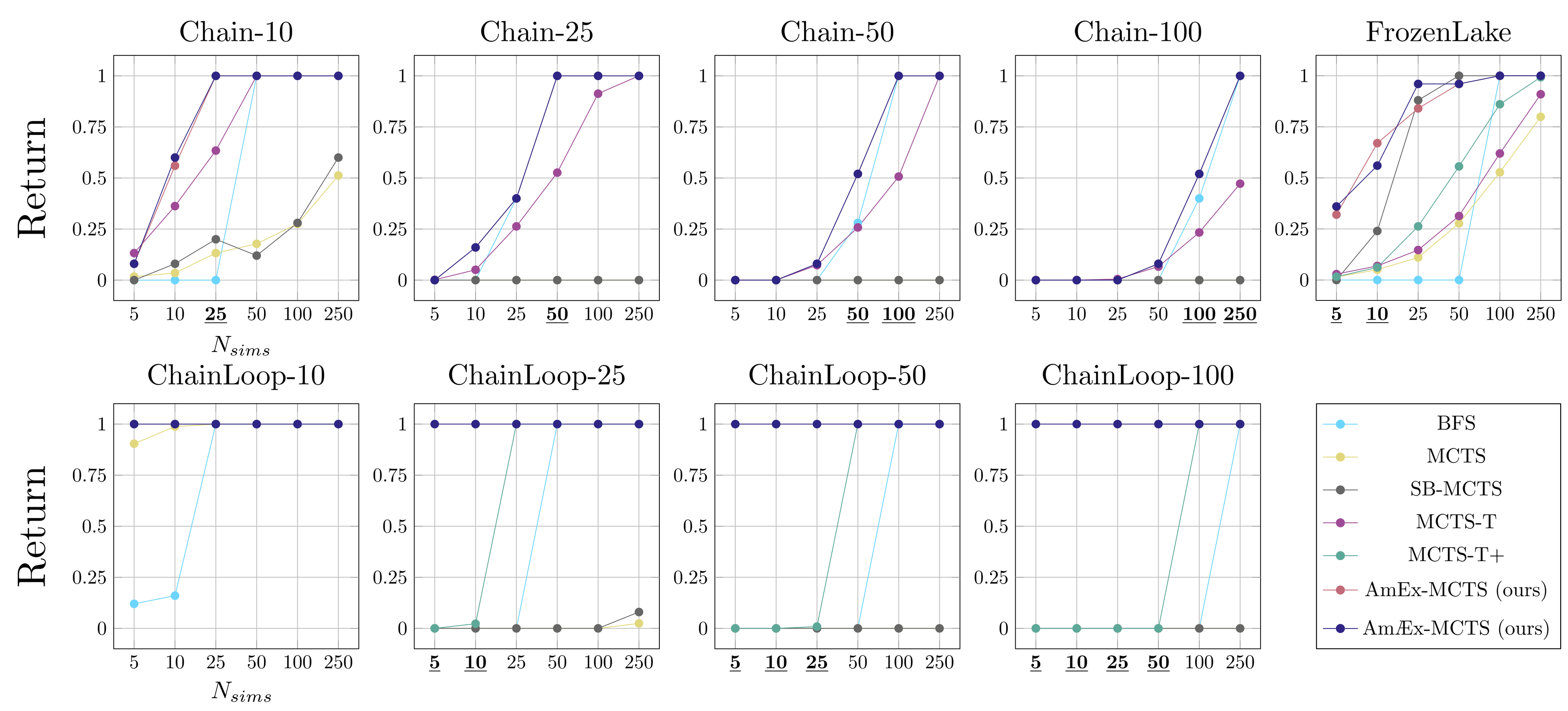
AmEx-MCTS **preserves the convergence and concentration properties** of classical MCTS while accelerating convergence in deterministic environments.

Results

1. AmEx-MCTS **explores a larger part of the search space** with minmal computational overhead.



2. **Ignoring completely explored subtrees leads to better performance** especially with limited resources. AmEx-MCTS consistently outperforms all baselines.



Take Away Message

Steering the exploration into unknown areas of the search space and **avoiding completely explored areas leads to a broader coverage** and **finds better solutions**.

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