Configuration Space Lattices to Infer (In)feasibility and Application to Rearrangement Planning*

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Rearrangement planning and task and motion planning (TAMP) typically integrate discrete task steps and their corresponding motion plans. A key aspect of integrating the discrete task planning space and continuous motion planning space is determining feasibility of motions. In rearrangement planning, we must know whether feasible motions exist from one arrangement to another arrangement [1, 7, 8, 10, 14]. In TAMP, each successive step must have feasible motions [2–6, 9, 11, 15–18].

In recent work, we proposed an algorithmic framework to construct motion planning infeasibility proofs [12, 13]. By forming a closure in the configuration space obstacle region that separates the start and the goal, we can prove the infeasibility of motion plans. The infeasibility proof is exact, which means encoding this information in task planning offers to prune invalid search branches without missing potentially feasible plans. Now, we investigate relations between configuration spaces to generalize both infeasibility proofs and valid plans in rearrangement and TAMP.

We define an algebraic lattice of configuration spaces to infer both feasibility and infeasibility of motion plans between different configuration spaces, and we apply this lattice inference to address efficiency and completeness of rearrangement planning. The lattice partial order is based on subset of obstacle regions; when one space's obstacle region is subset of another, we can transfer infeasibility proofs and motion plans between the spaces, offering a generalized notion of "inheriting" plans or infeasibility proofs. We apply this lattice inference to rearrangement planning by identifying infeasibility proofs to encode as additional task planning constraints. Further, if task planning constraints eliminate all possible plans due to infeasible motion, we then conclude infeasibility of the TAMP problem, offering completeness guarantees beyond previous work on TAMP and rearrangement planning. Our key contributions are as follows:

- ☞ Define and apply the subset relation on configuration spaces to form an algebraic lattice;
- ☞ Develop an algorithm to encode motion planning infeasibility proof results in task planning, leading to asymptotically complete TAMP;
- ☞ Computational experiments to demonstrate our algorithm's effectiveness.

* This work is supported in part by ARL TBAM-CRP [W911NF- 22-2-0235].

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