Task-Based Design of Ad-hoc Modular Manipulators

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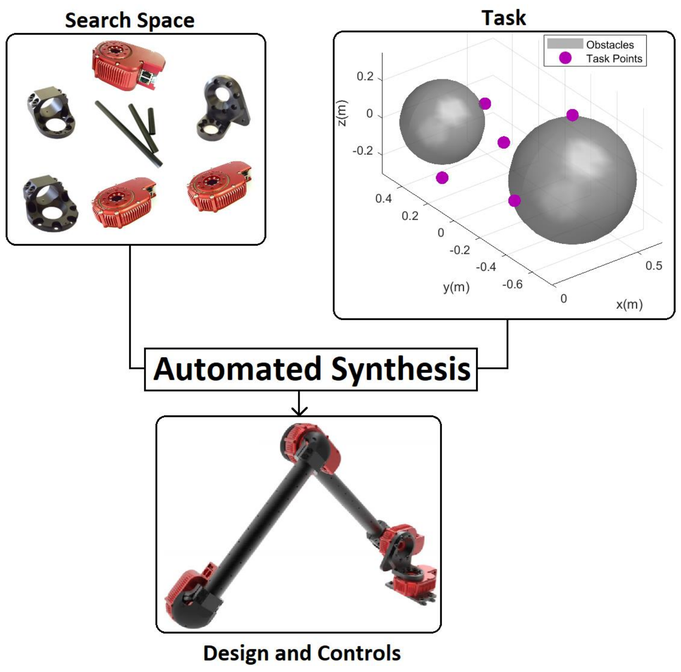
INTRODUCTION

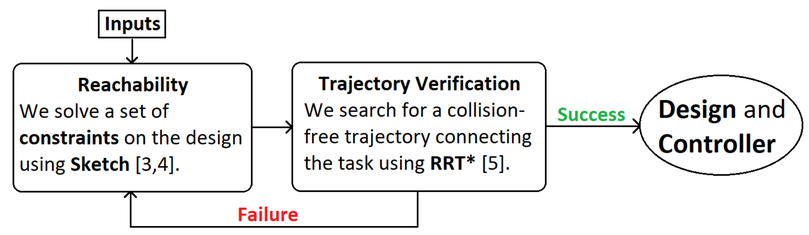
- **Modular robots** can be arranged in different configurations to perform a **variety of tasks** [1,2].
- Finding a **configuration** to perform a **specific task** can be **challenging** due to the **large design space**.
- In our approach, we **automatically synthesize** task specific **configuration** and **controls** for **modular manipulators.**



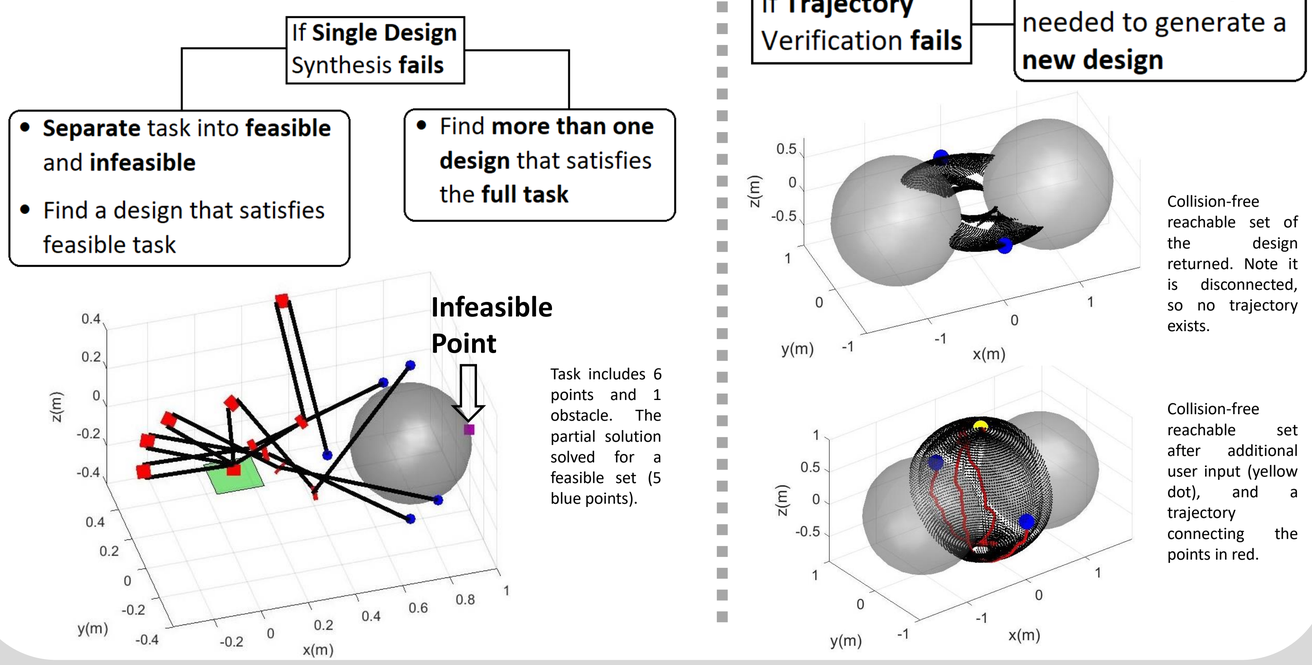
The search space consists of one DoF actuators (Hebi Robotics X-Series depicted), mounting brackets and link lengths; The task input is a set of points in 3D space as well as spherical obstacles in the environment. Our approach automatically synthesizes provably-correct design and controls to reach the task points.

APPROACH

- **Problem**: find **a design and controller** that reach all **task points** in a single **trajectory**.
- Our approach can also handle **partially infeasible tasks**.
- Our approach is composed of **two parts**:



- If **no solution** is found:



RESULTS

1. Comparison with Genetic Algorithm (GA)

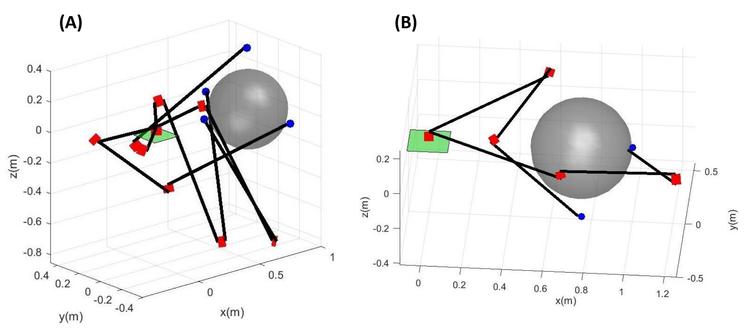
		GA		Sketch	
Task	DoFs	% Success	Runtime (s)	% Success	Runtime (s)
9 points	2	60	125.1± 6.4	100	9.9± 5.3
	3	100	311.9± 115.7	100	6.1± 5.2
	4	100	211.5 ± 5.1	100	32.7± 13.7

Table 1. Rate of success for a feasible task in an environment without obstacles for GA and Sketch.

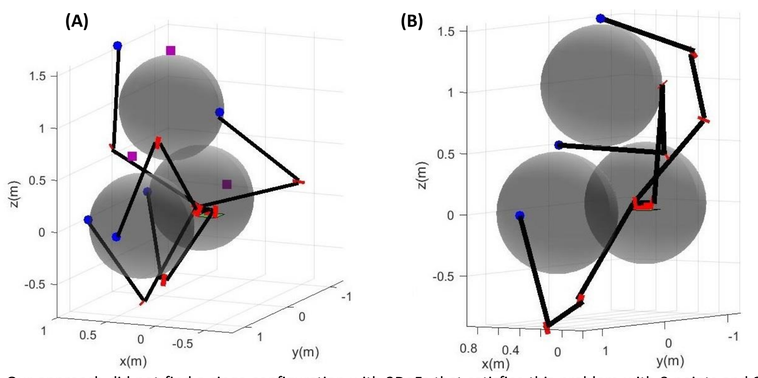
Obstacle Radius (m)	GA solved?	Runtime	Sketch solved?	Runtime
0.2	Yes	2.3s	Yes	3.1s
0.4	Yes	48.47m	Yes	2.8s
0.6	No	-	Yes	9.4s
0.8	No	-	Yes	13.6s
1.0	No	-	Yes	10.6s

Table 2. GA and Sketch results for environment with 1 obstacle, 5 task points and design with 3DoFs.

2. Partially Infeasible task



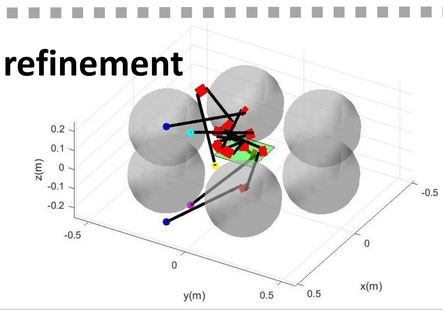
Designs found for problem with 1 obstacle and 6 task points. (A) First configuration reaching 4 of the 6 task points. (B) Second configuration reaching the other 2 task points.



Our approach did not find a singe configuration with 3DoFs that satisfies this problem with 8 points and 3 obstacles. (A) The task is divided into feasible (blue dots) and infeasible (purple squares) and a configuration with 3DoFs was found. (B) For the infeasible task, our approach found a solution with 4DoFs.

3. Iterative task refinement

Complex environment that needed multiple user inputs. Blue dots are the original task. Yellow dot was the first user addition, magenta, the second, and cyan, the third.



CONCLUSIONS

- Our framework **synthesizes provably-correct** task-based designs for **manipulators.**
- It can handle **partially infeasible tasks.**
- It can generate **more than one configuration** if a single one cannot accomplish the full task.
- It **outperforms GA** in **constrained environments**.
- Limitations: our approach is not complete and it might require user input.
- In the future, we will encode more complex tasks (e.g. follow trajectory) and additional physical constraints (e.g. torque limit).

ACKNOWLEDMENTS

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