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Evolving Superhuman Algorithms for Long-Horizon Planning

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Mathematical discoveries from program search with large language models

Bernardino Romera-Paredes, Mohammadamin Barekatain, Alexander Novikov, Matej Balog, M. Pawan Kumar, Emilien Dupont, Francisco J. R. Ruiz, Jordan S. Ellenberg, Pengming Wang, Omar Fawzi, Pushmeet Kohli & Alhussein Fawzi

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Google DeepMind

UNIVERSITY OF CAMBRIDGE

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Build algorithmic superintelligence

The Hive

"Don't EVER make the mistake that you can design something better than what you get from ruthless **massively parallel trial-and-error with a feedback cycle**."

Linus Torvalds, 2001

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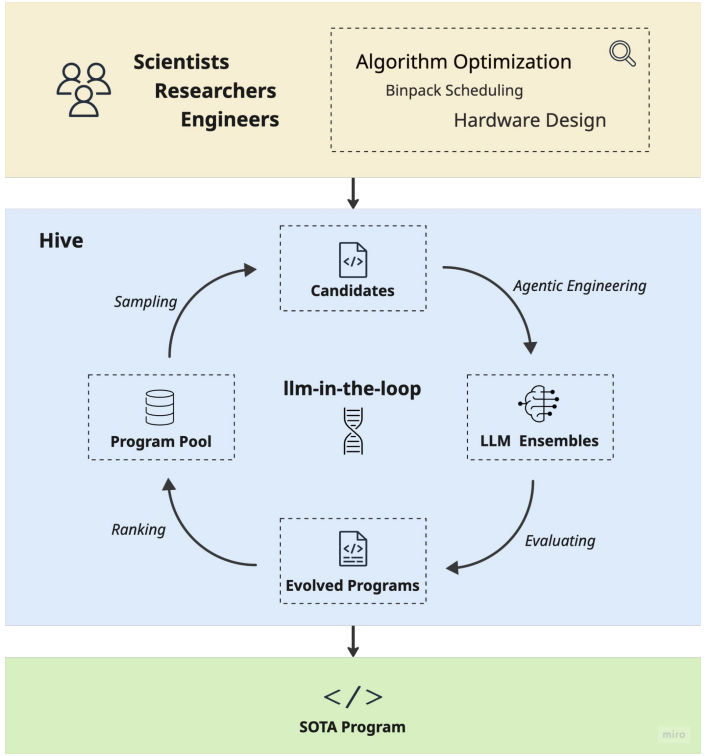
The Hive



"Don't EVER make the mistake that you can design something better than what you get from ruthless **massively parallel trial-and-error with a feedback cycle**."

Linus Torvalds, 2001

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The Hive

A distributed code optimization agent that autonomously finds the most effective algorithms for a given task

Useful for problems where we can implement granular automated evals, such as:

- Planning & scheduling
  - Airline optimization
  - Multi-stage production scheduling
  - Electronic chip design
  - ...
- Runtime performance optimization
  - Algorithms to train AI models
- ...

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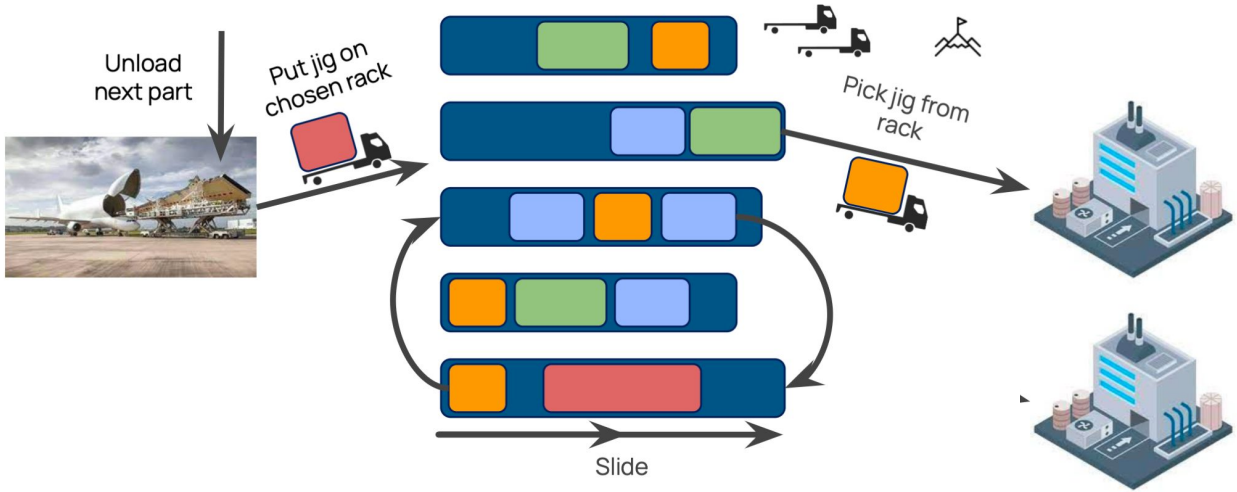
The Airbus Beluga problem



plan

1. pickup (jig1,ftrailer1,rack1,factory)
2. deliver (jig1,hangar1,ftrailer1,pl2)
3. pickup (jig3,btrailer1,rack0,beluga)
4. load (jig3,beluga1,btrailer1)
5. switch_to_next_beluga()
6. pickup(jig,btrailer1,rack0,beluga)
7. load (jig2,beluga2,btrailer1)
8. switch_to_next_beluga()
9. unload (jig4,beluga3,btrailer1)
10. putdown (jig4,btrailer1,rack0,beluga)
11. get_from_hangar(jig1,hangar1,ftrailer1)
12. putdown (jig1,ftrailer1,rack1,factory)
13. pickup (jig4,ftrailer1,rack0,factory)
14. deliver (jig4,hangar1,ftrailer1,pl0)
15. switch_to_next_beluga()
16. pickup (jig1,btrailer1,rack1,beluga)
17. Load (jig1,beluga4,btrailer1)
18. switch_to_next_beluga()
19. unload (jig5,beluga5,btrailer1)

Key challenges:

Limited number of resources (e.g. racks): Poor management → no solution

Problem scale: some problems involve over 800 aircraft parts!

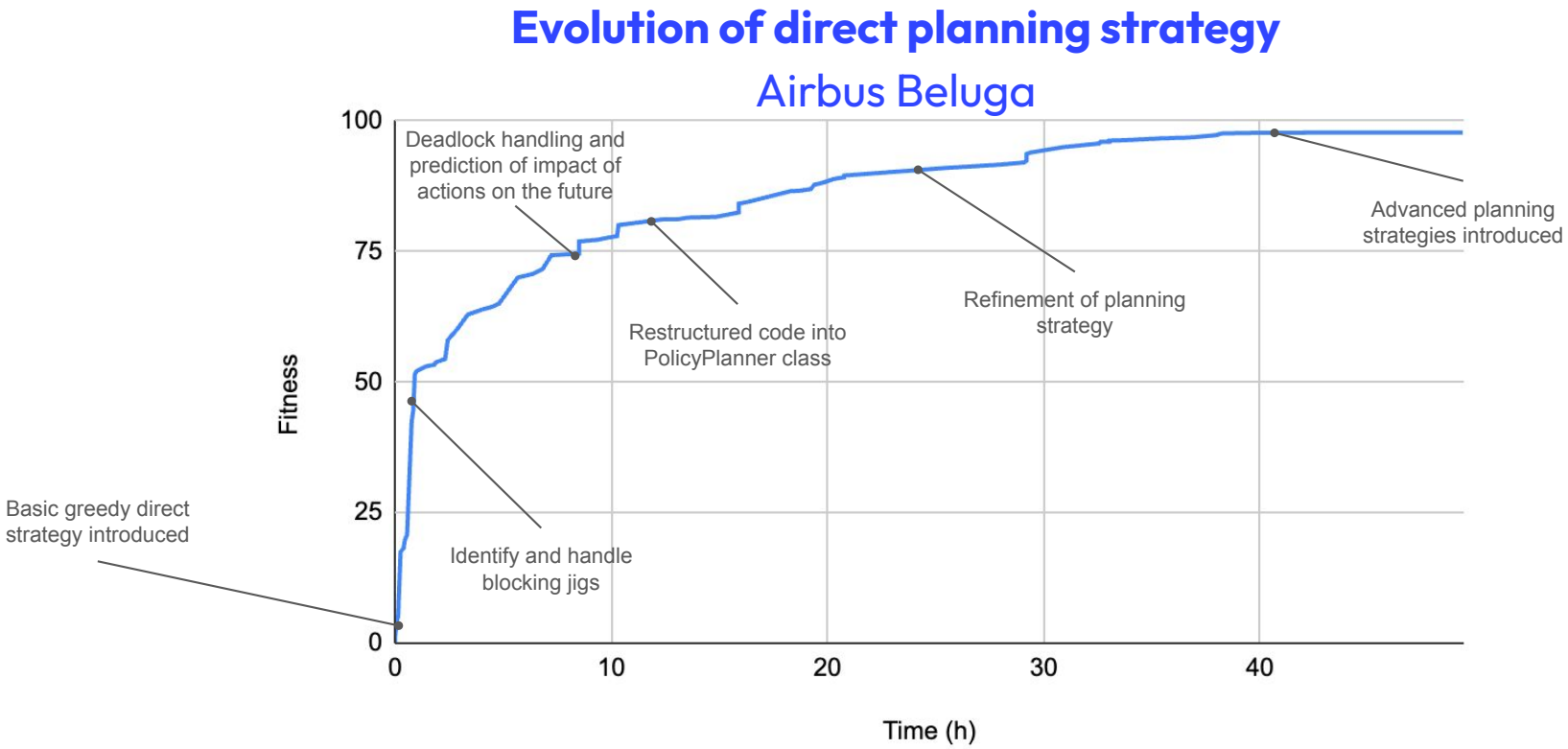
The Airbus Beluga problem

Business pain points: complex & combinatorial problem currently planned manually by 2-3 teams

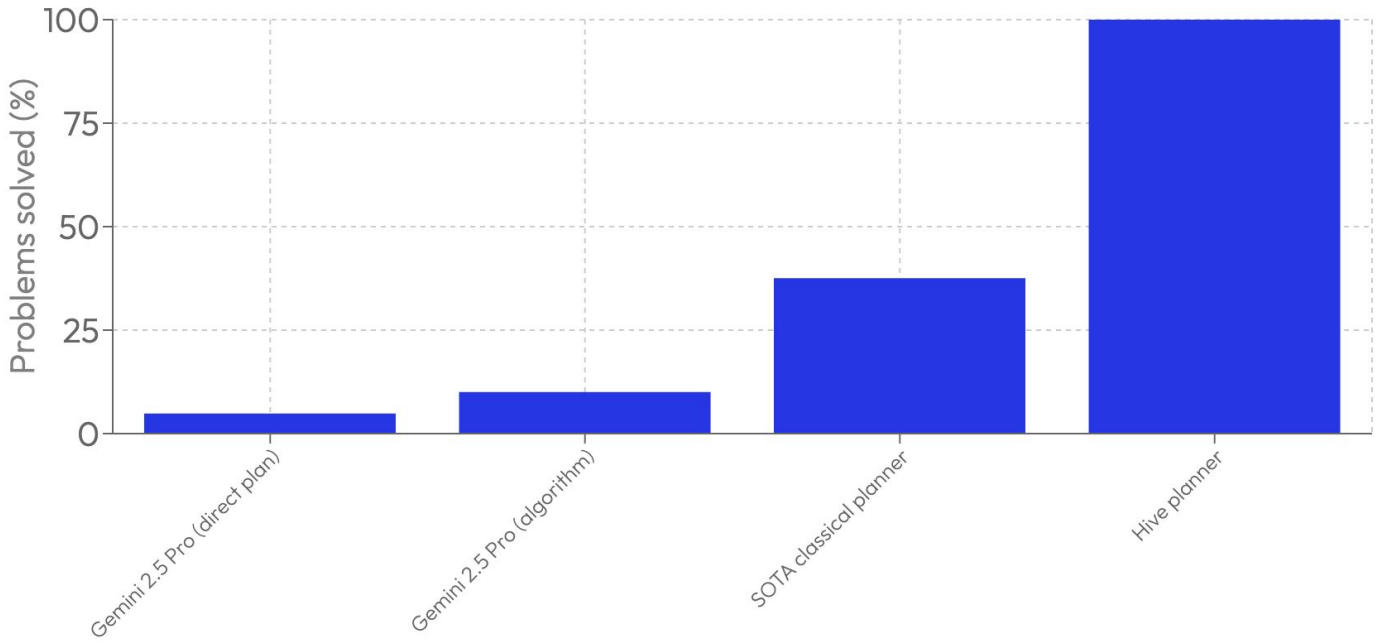
We won **first place** in both the Scalability Deterministic and the Scalability Probabilistic challenges.

Demo

Code evolution introduces key planning elements



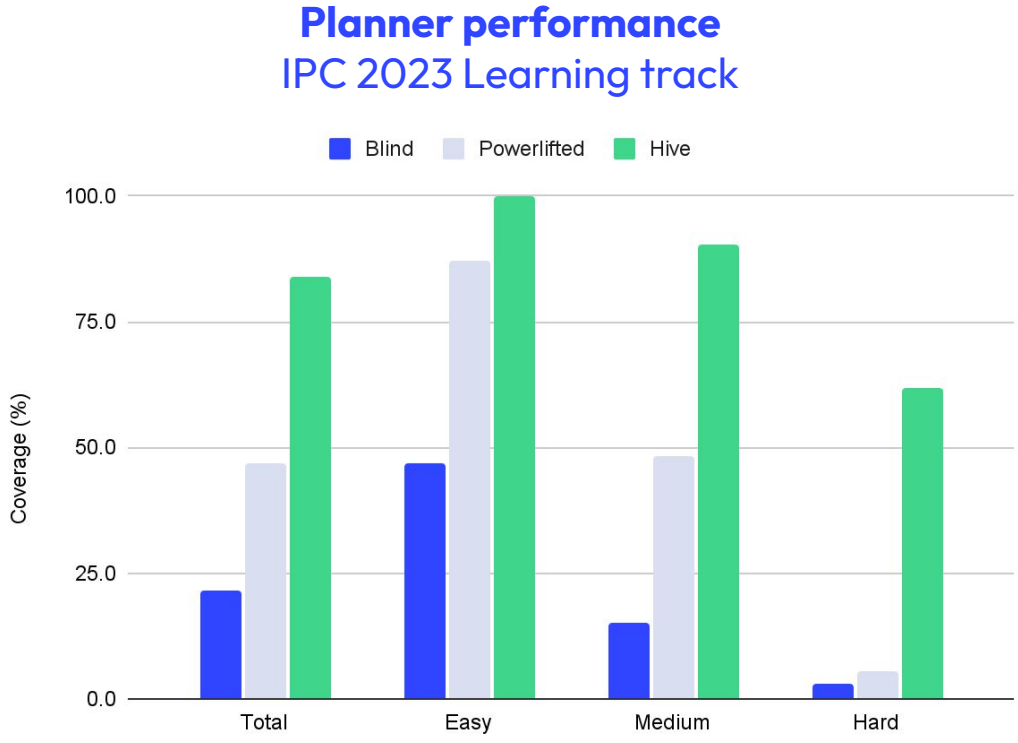
Comparison of planners on Airbus Beluga



Our approach is generalizable to other planning problems

Constraint: problem expressed in PDDL

Scope: Approach tested on 10 different planning domains from the International Planning Competition 2023 Learning track



The Hive vs other optimization methods

	Adaptable	Explainable	Safe	Easy to deploy	Scalable
Formal methods	✗	✓	✓✓	✓✓	✗
Learning methods	✓✓	✗	✗	✗	✓
The Hive	✓✓	✓✓	✓✓	✓✓	✓✓

The Hive: connecting LLM agents with evaluators

- Multiple LLM agents and simulators running in parallel

The Hive: connecting LLM agents with simulators

- Multiple LLM agents and simulators running in parallel
- Real life applications rolled-out

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Thank you