OpenTuner

An Extensible Framework for Program Autotuning

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Goal

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Modify configuration → tune software heuristic, e.g.,

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- Program size

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- Time

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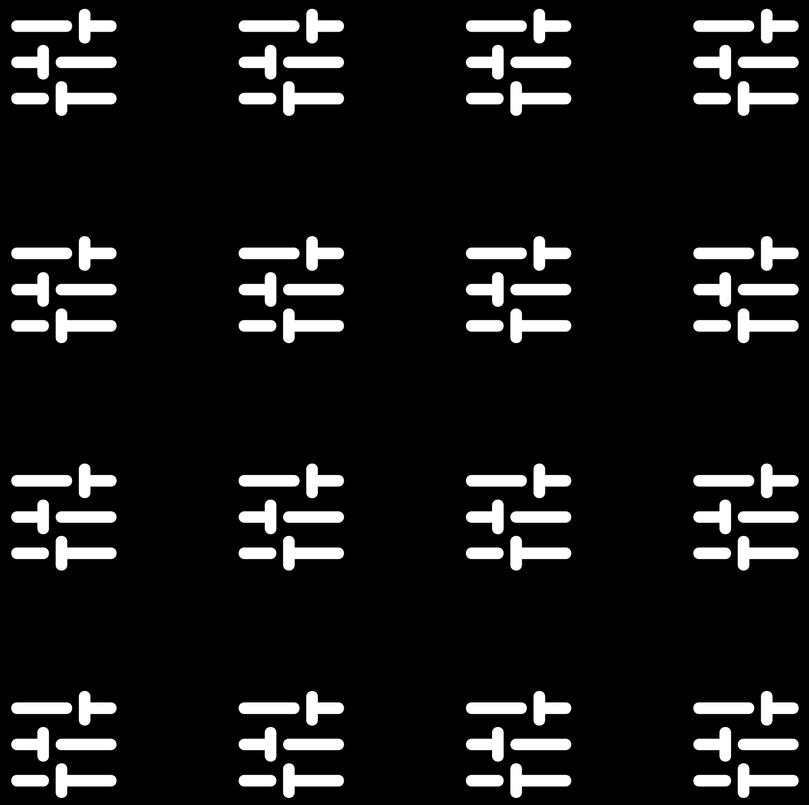
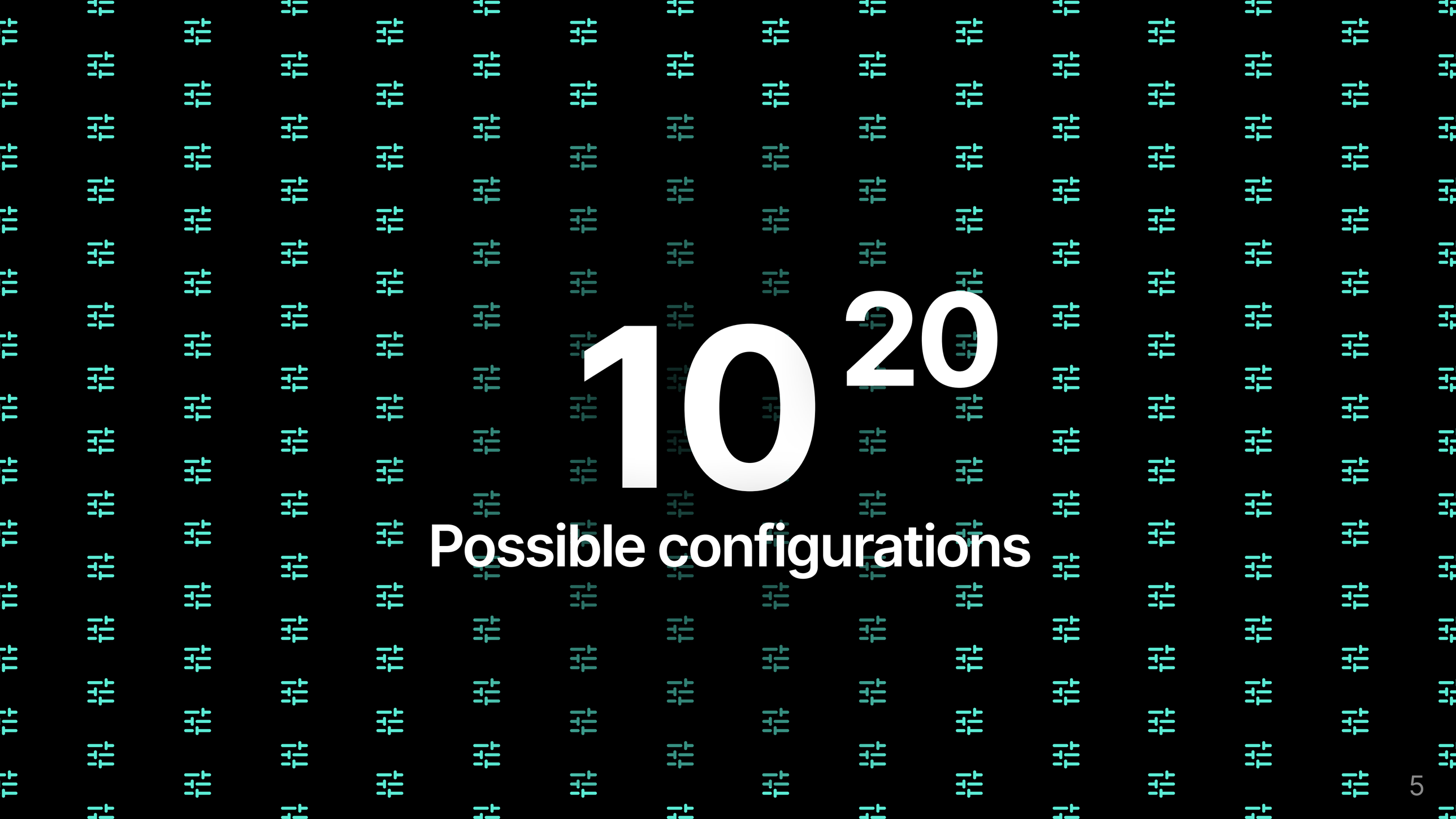
- Resource usage (e.g., memory)

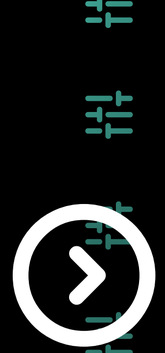
Goal

Modify configuration → tune software heuristic, e.g.,

- Program size
- Time
- Resource usage (e.g., memory)
- Energy consumption




10^{20}
Possible configurations



10 3600

Possible configurations

Autotuning

Autotuning

Challenges

Autotuning

Challenges

1 **Configuration Representation**
Need domain-informed configuration space representation

Autotuning

Challenges

1. **Configuration Representation**
   Need domain-informed configuration space representation

2. **Configuration Space Size**
   Need search technique

Autotuning

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3. **Configuration Space Landscape**
   Continuity? Dimensionality? Coupled parameters?

Autotuning

Challenges

1. **Configuration Representation**
   Need domain-informed configuration space representation

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3. **Configuration Space Landscape**
   Continuity? Dimensionality? Coupled parameters?

? **Effect on search techniques?**

Configuration Space Landscape

Technique – Hill Climber Optimisation

Configuration Space Landscape

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Configuration Space Landscape
Discontinuities, Smaller Hills, Plateaus, Coupling

Configuration Space Landscape

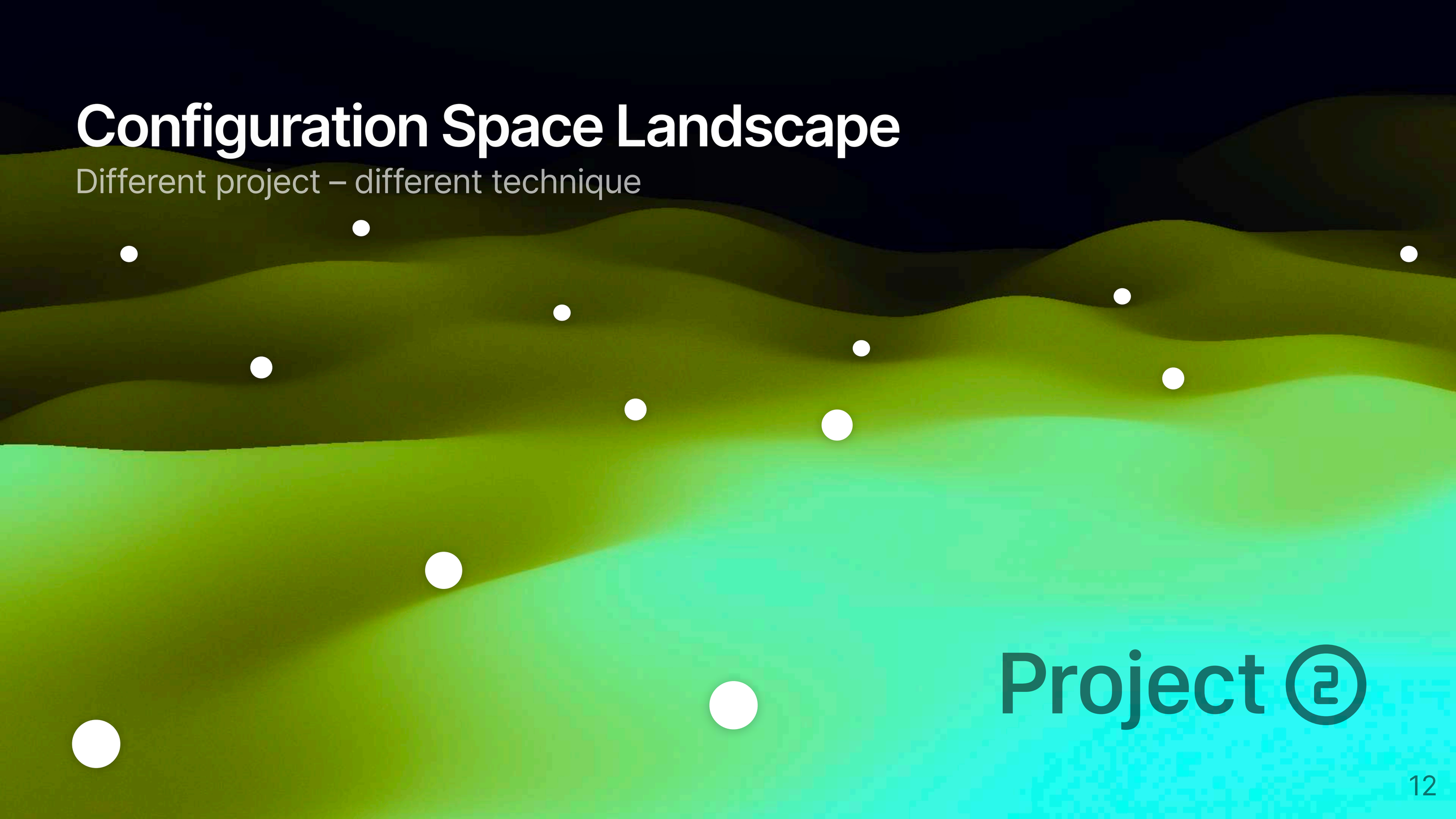
Discontinuities, Smaller Hills, Plateaus, Coupling

Configuration Space Landscape

Different project – different technique

Configuration Space Landscape

Different project – different technique



Project 2

Autotuning

Challenges

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   Need domain-informed configuration space representation

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Autotuning

Challenges

1 **Configuration Representation**
Need domain-informed configuration space representation

2 **Configuration Space Size**
Need search technique

3 **Configuration Space Landscape**
Continuity? Dimensionality? Coupled parameters?

? **Search technique efficacy depends heavily on landscape (→ on project)**
Previous work: Custom representations & techniques for specific problem

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Search

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Use multiple search techniques
(“Ensemble”) simultaneously

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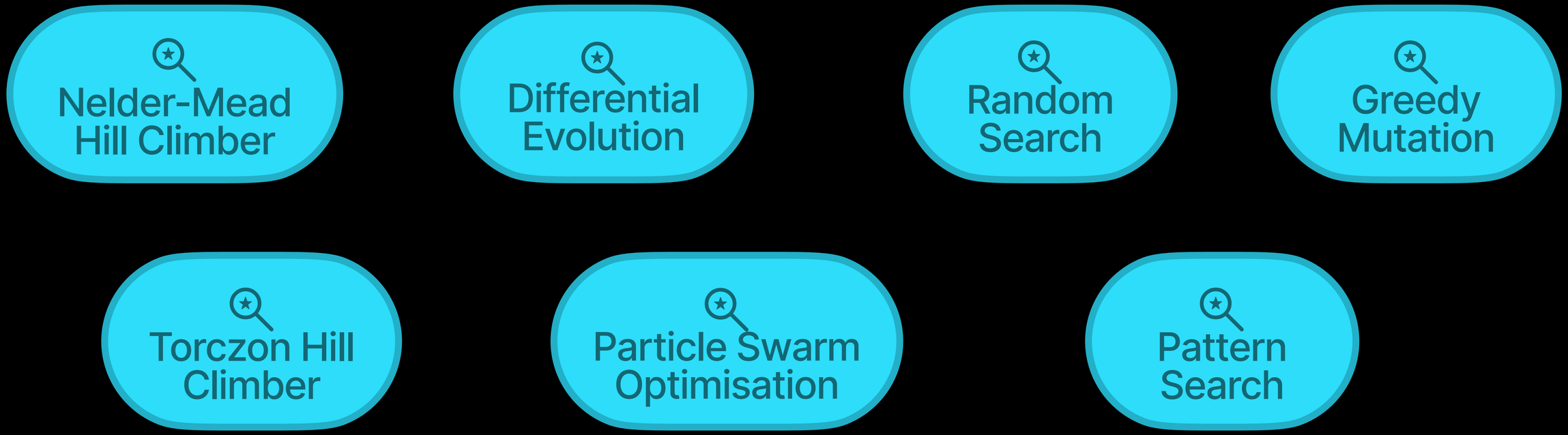

OpenTuner

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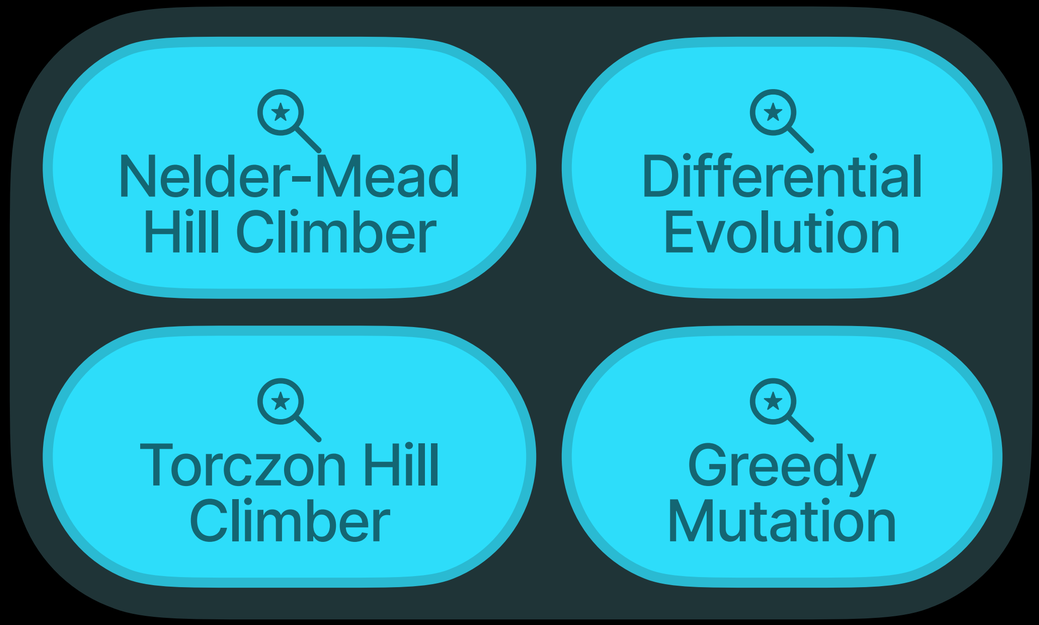
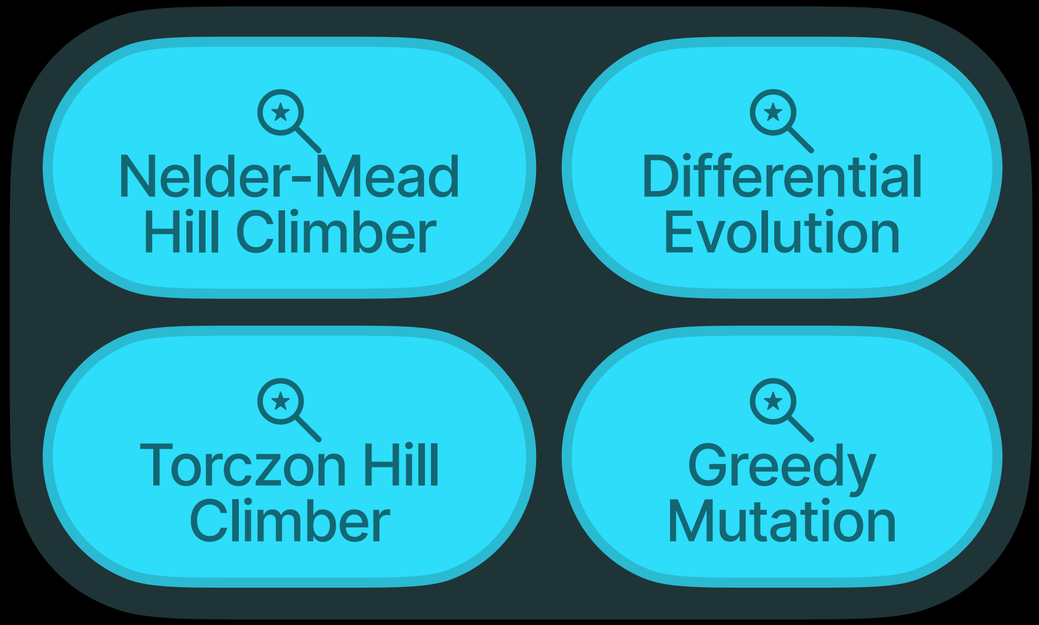


OpenTuner

Search

Use multiple search techniques (“Ensemble”) simultaneously

Meta techniques group techniques



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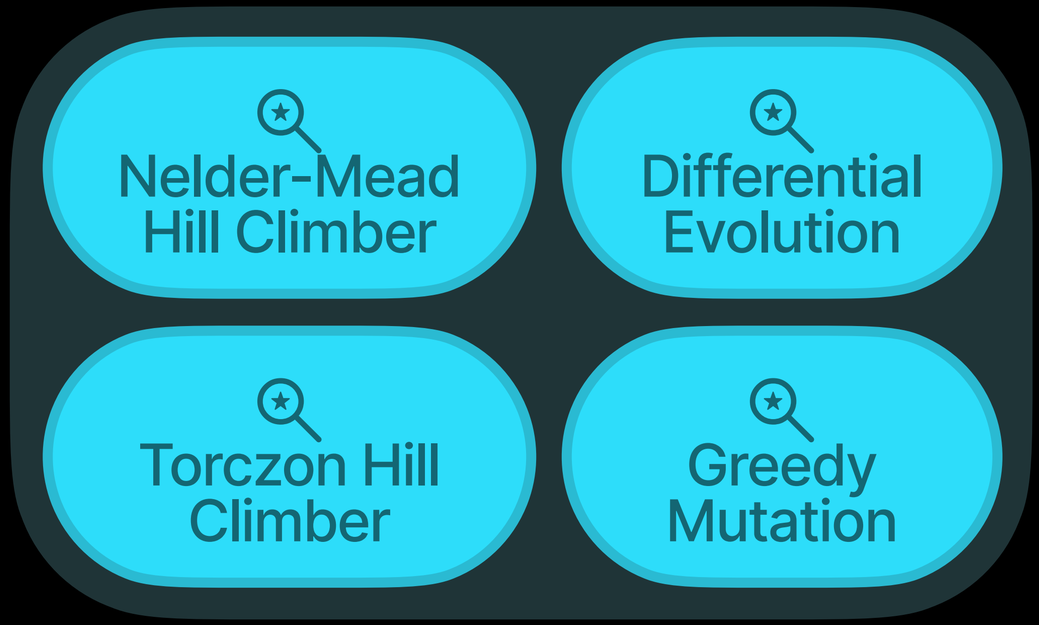
Can nest (meta) techniques



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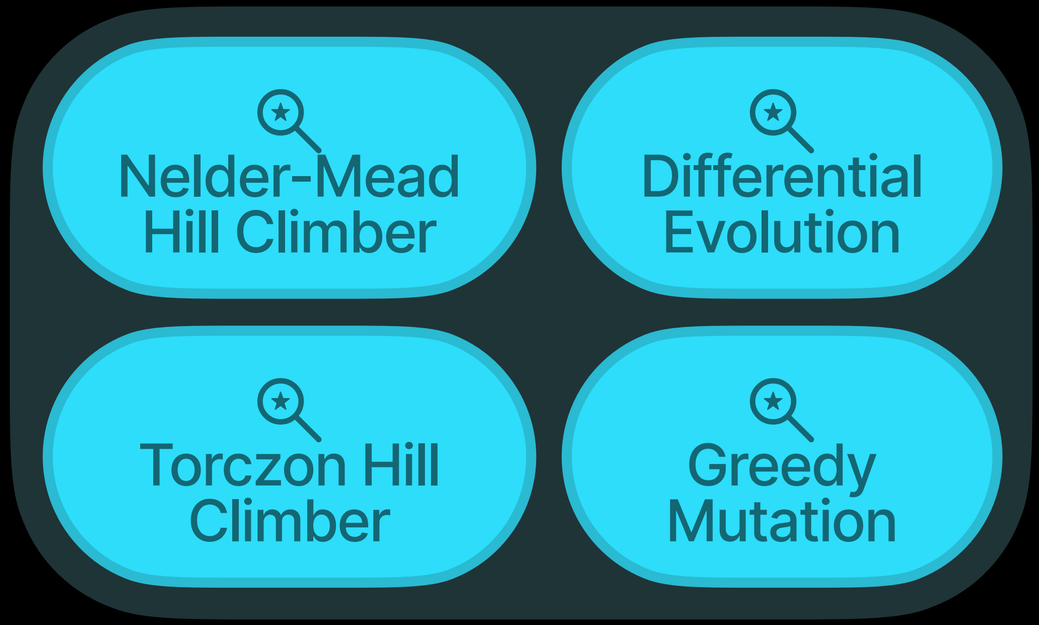
Dynamically allocate test runs to sub-techniques
(e.g., Round Robin, Multi-armed bandit)



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EXPLOITATION + **EXPLORATION**

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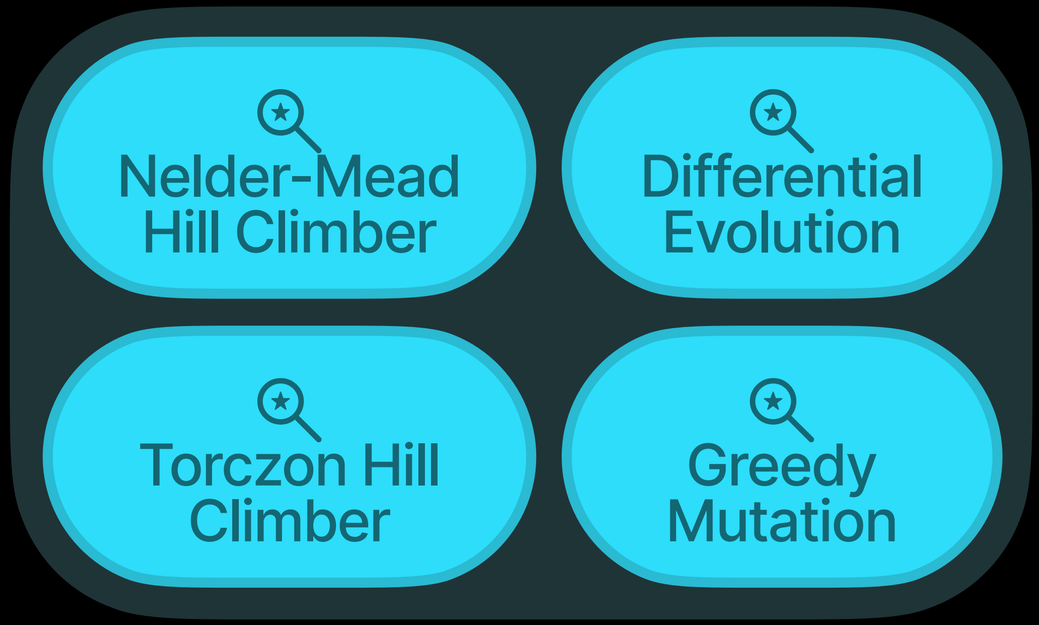

$$\text{argmax}_T \left(\frac{2}{|V_T|(|V_T|+1)} \sum_{i=0}^{|V_T|} i\,V_{i,T} + C\sqrt{\frac{2\lg|H|}{|V_T|}} \right)$$

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Components

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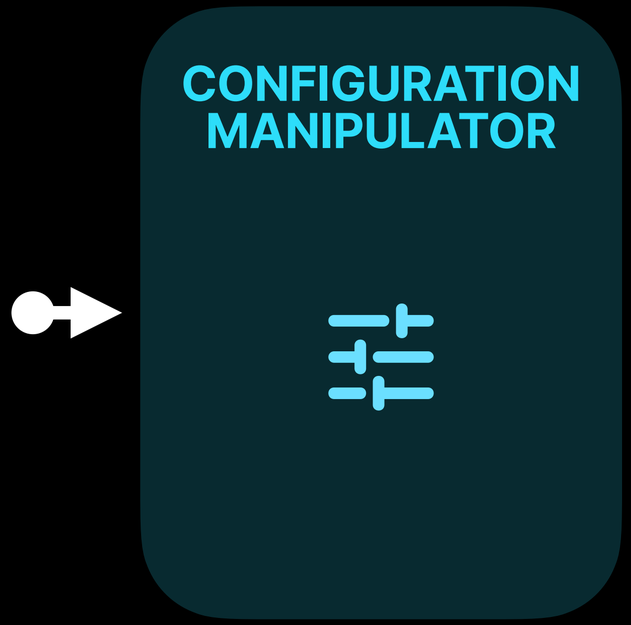

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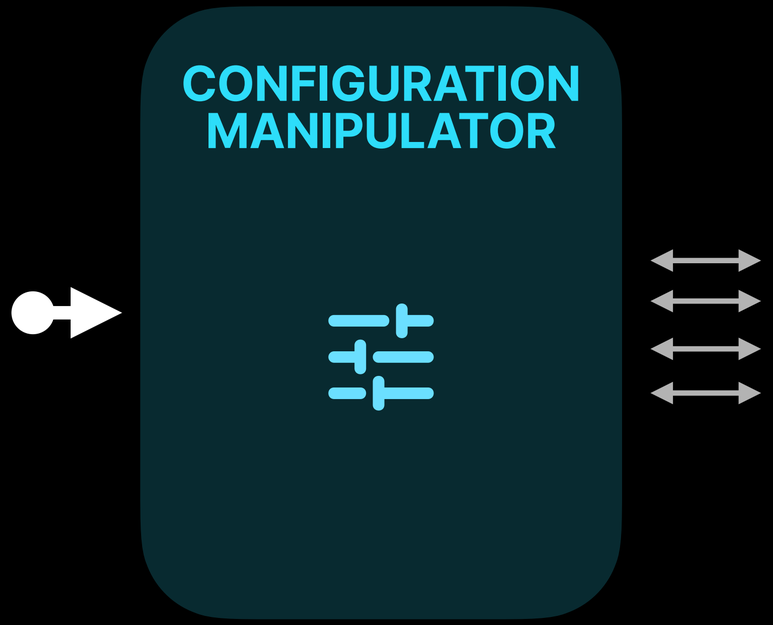

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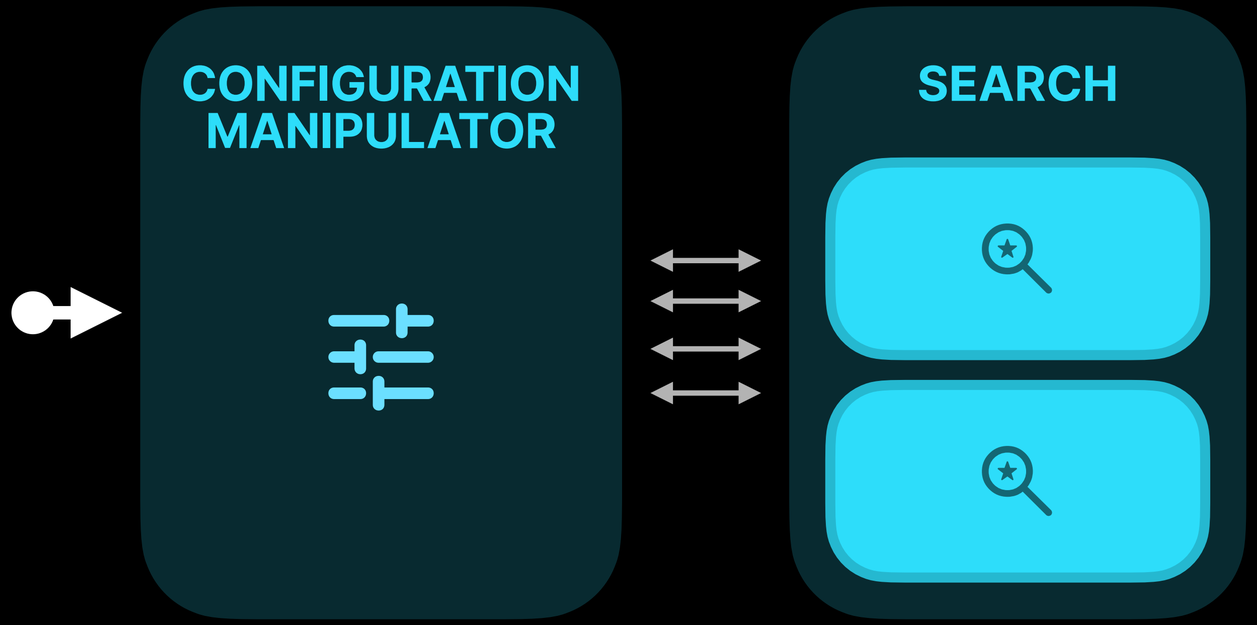

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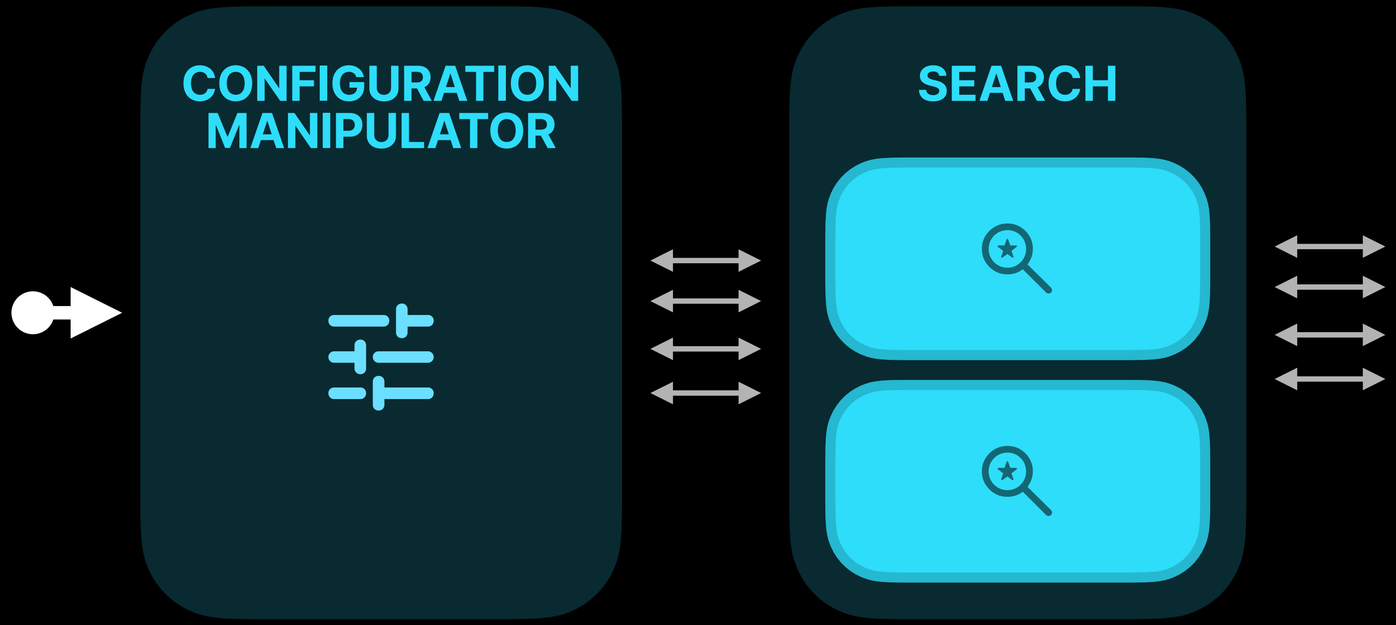

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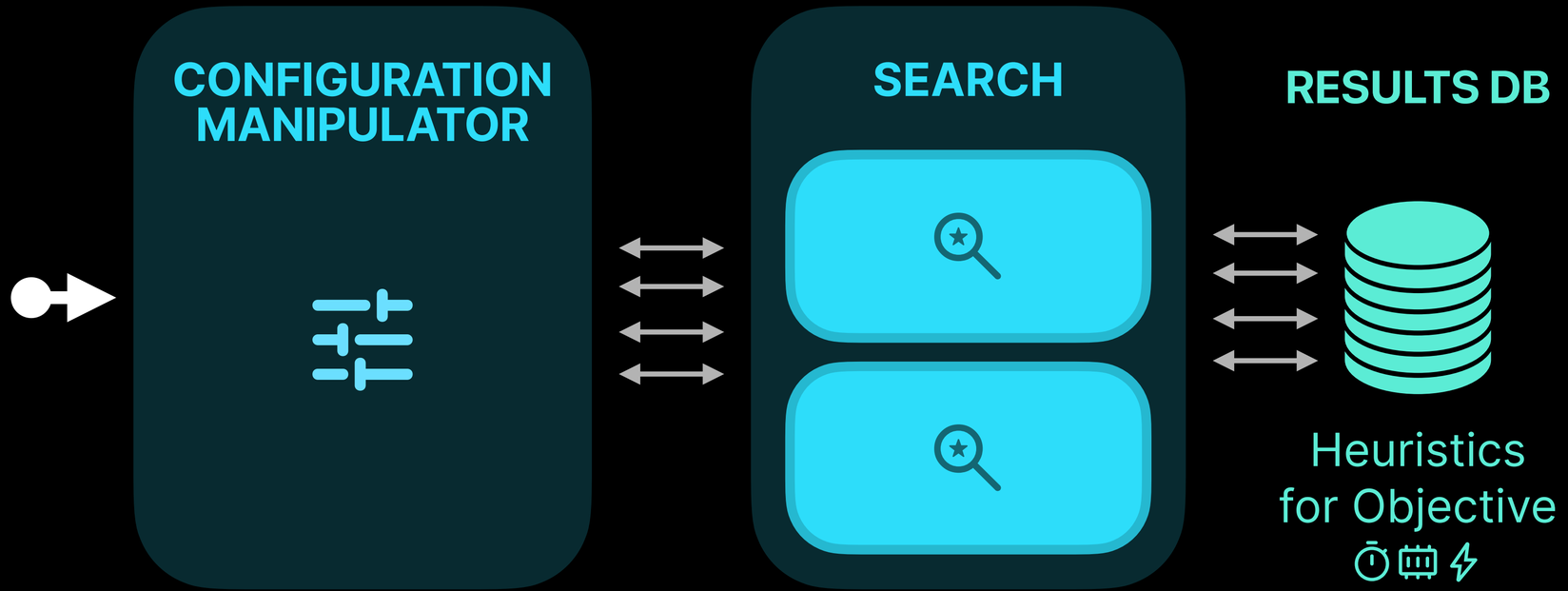

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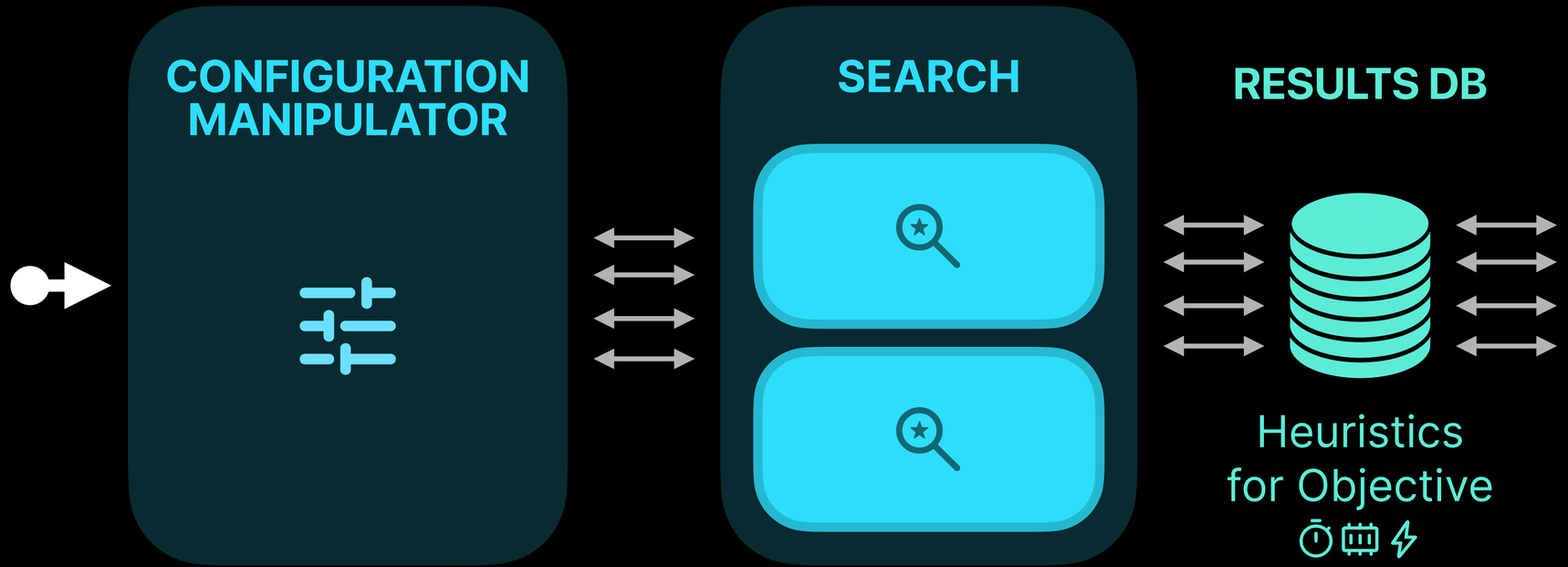

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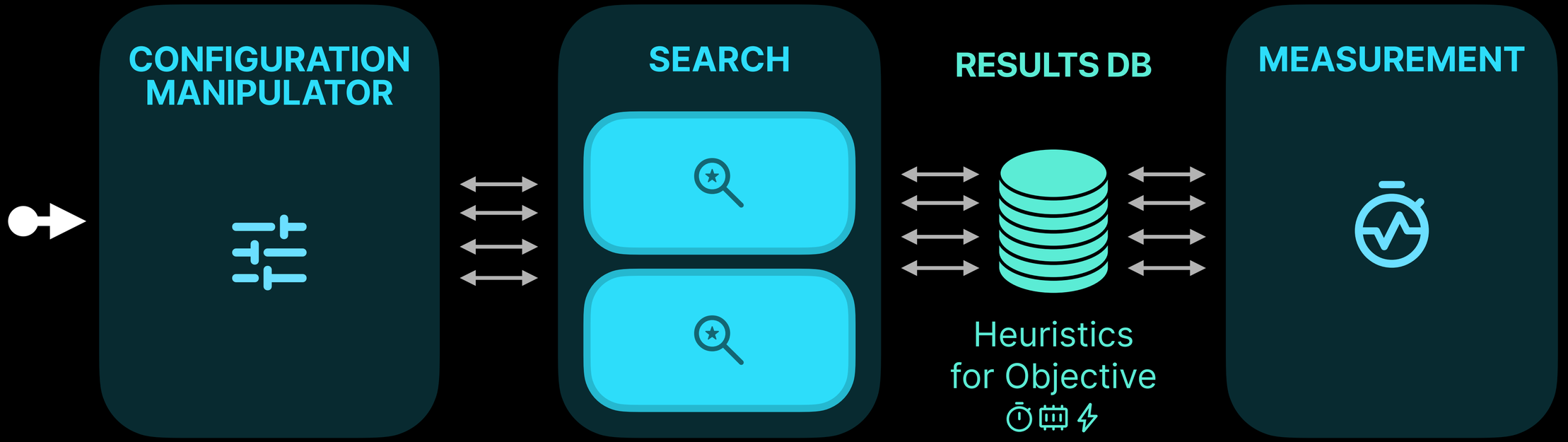

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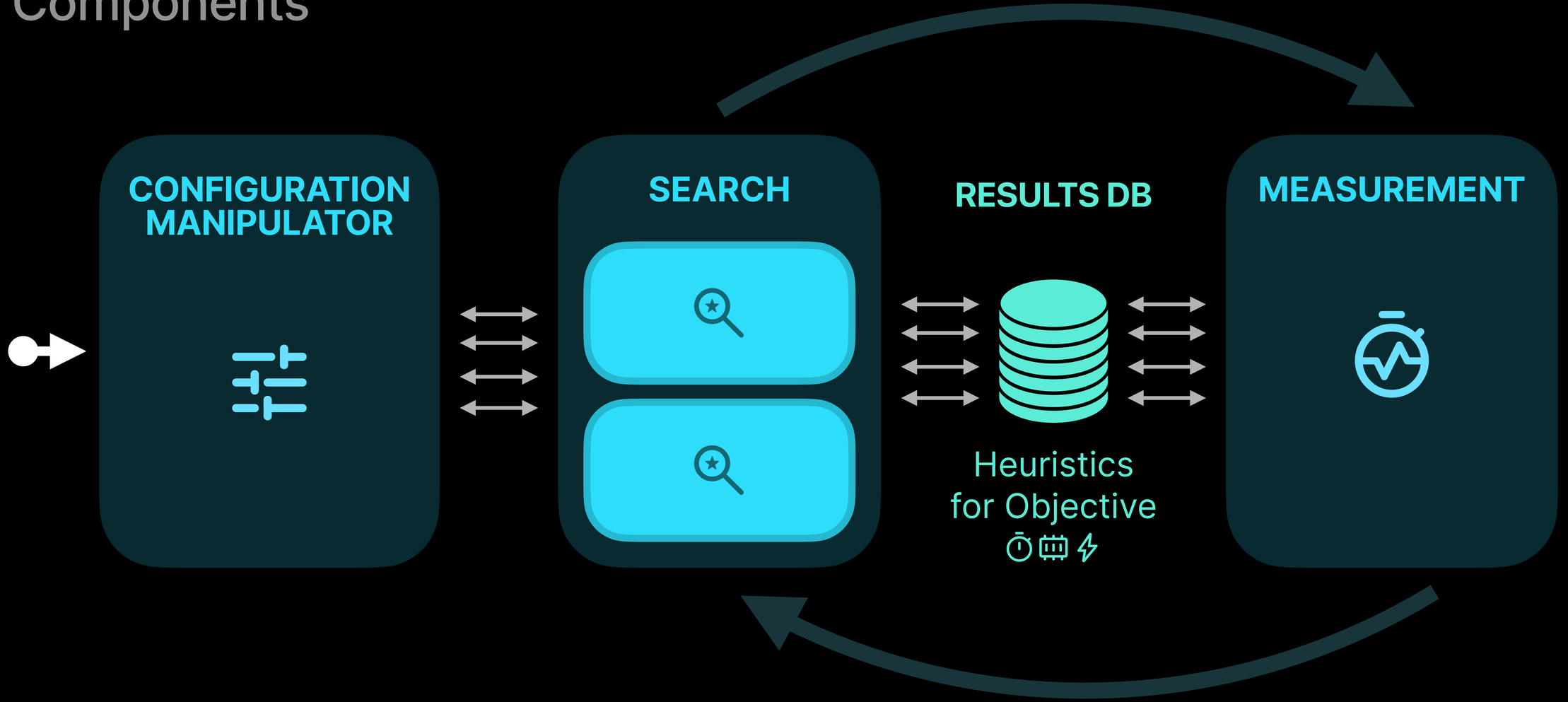

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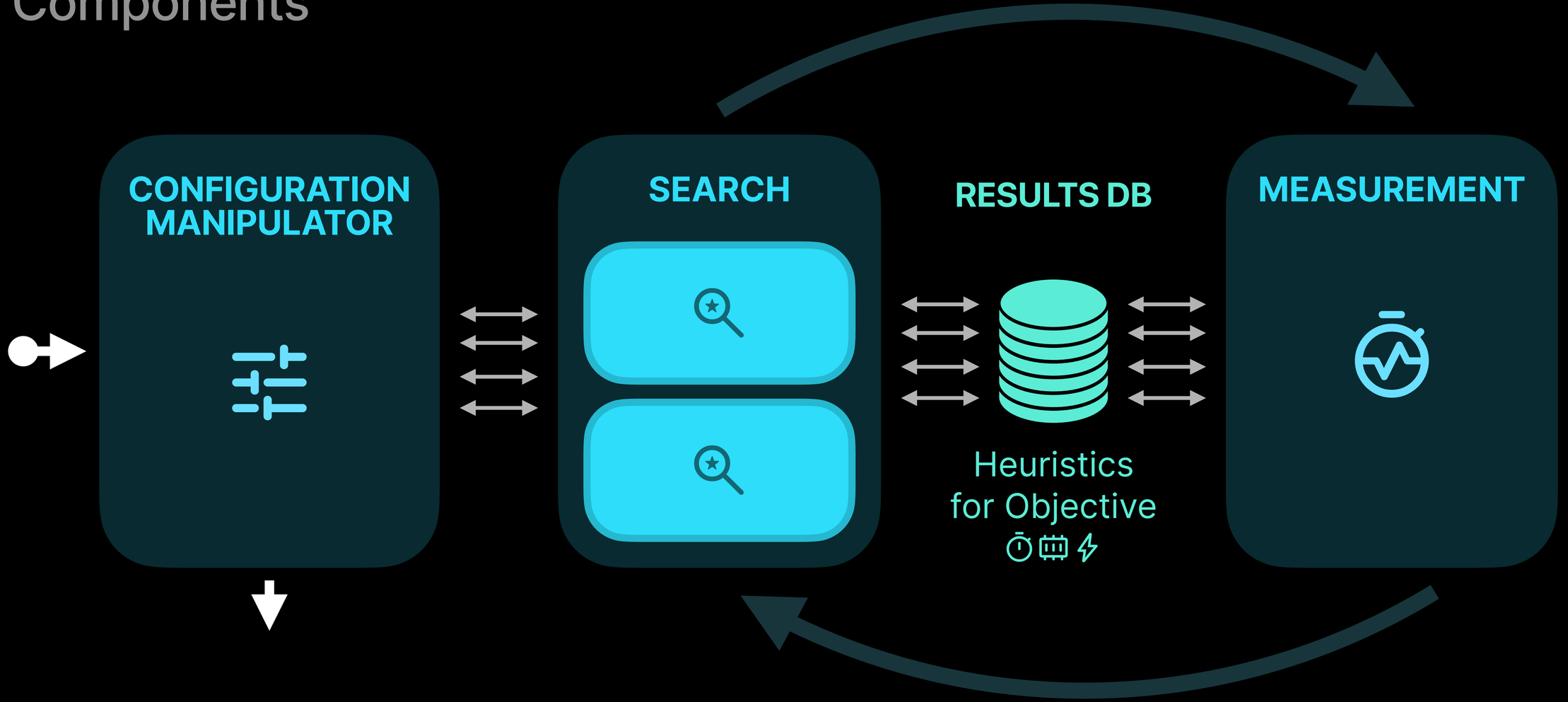

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Solutions

1. Configuration Representation

2. Configuration Space Size
3. Configuration Space Landscape

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Solutions

1. **Configuration Representation**
   Python abstraction (API): primitive, complex, custom data types
2. **Configuration Space Size**
3. **Configuration Space Landscape**

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Solutions

1. **Configuration Representation**
   Python abstraction (API): primitive, complex, custom data types

2. **Configuration Space Size**

3. **Configuration Space Landscape**
   Ensemble of search techniques:
   concurrent, dynamic evaluation budget allocation, cooperative

Evaluation

Evaluation

- ☑ 7 different project with different configuration representations

Evaluation

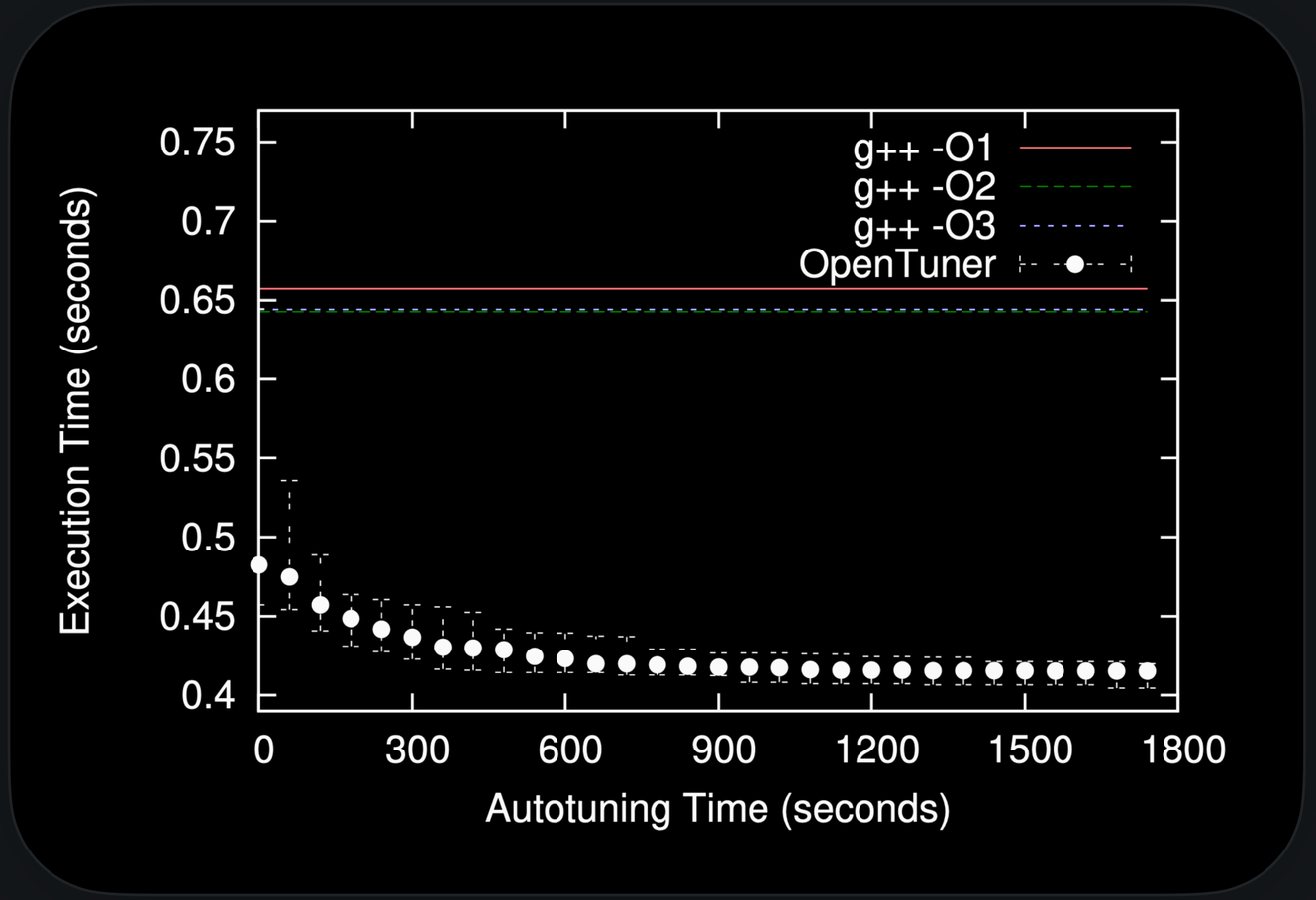
- [x] 7 different project with different configuration representations
- [x] Heuristic tuned to manual equivalent or optimum

Evaluation

- ☑ 7 different project with different configuration representations
- ☑ Heuristic tuned to manual equivalent or optimum
- ☑ Domain-specific success

Evaluation

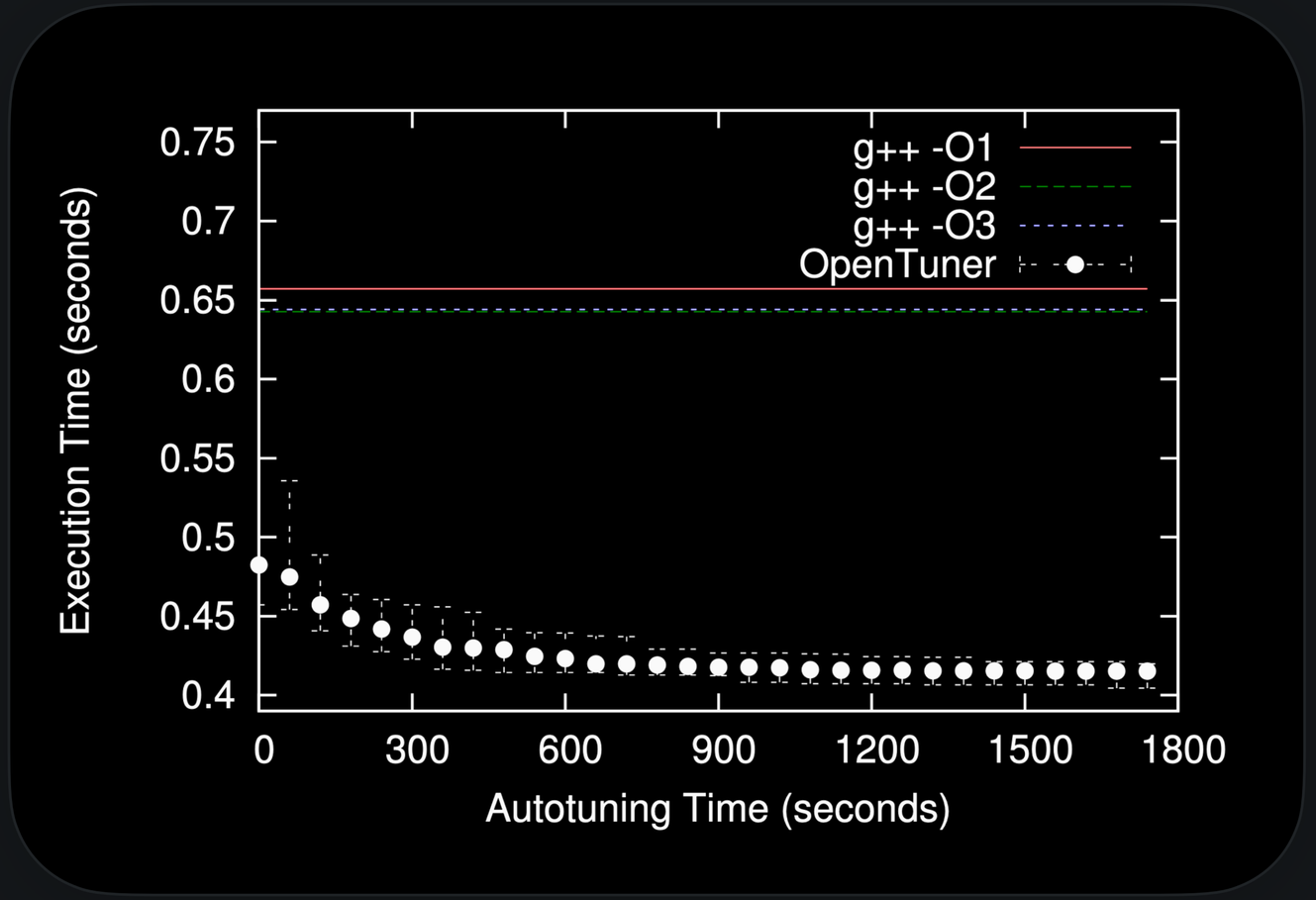
Experiment – GCC Flags



Evaluation

Experiment – GCC Flags

CONFIGURATION

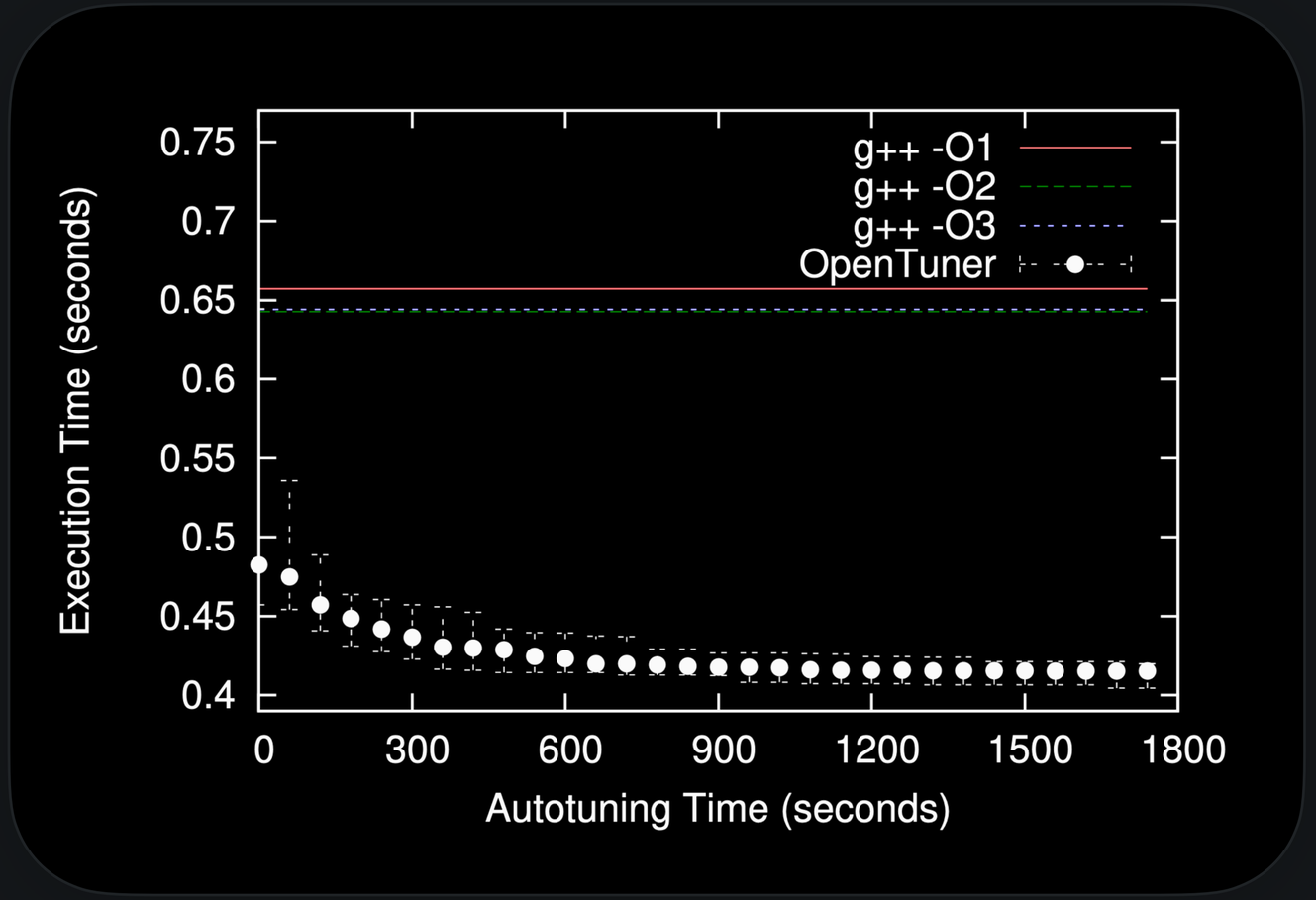


Evaluation

Experiment – GCC Flags

CONFIGURATION

Compiler flags



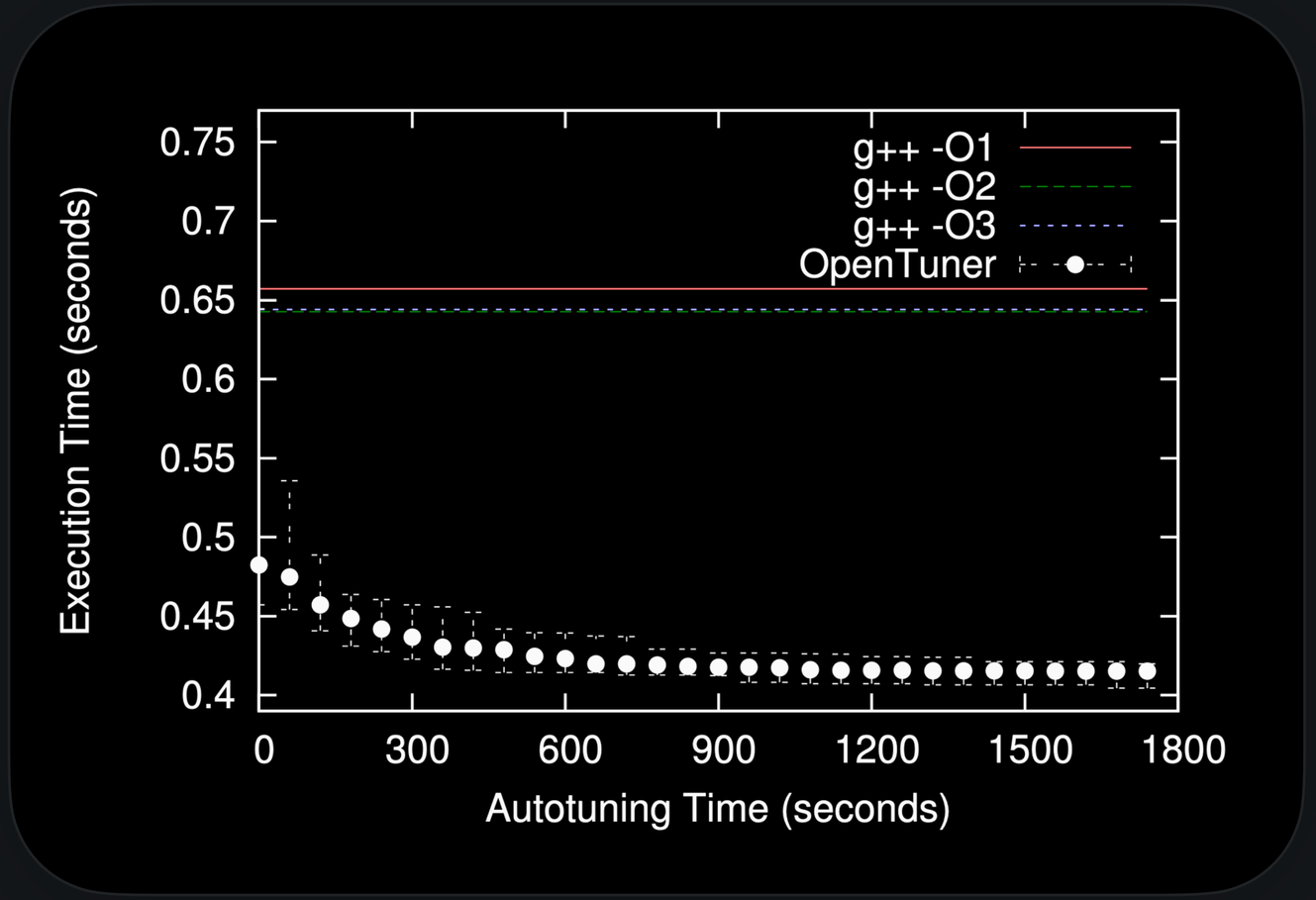
Evaluation

Experiment – GCC Flags

CONFIGURATION

Compiler flags

OBJECTIVE



Evaluation

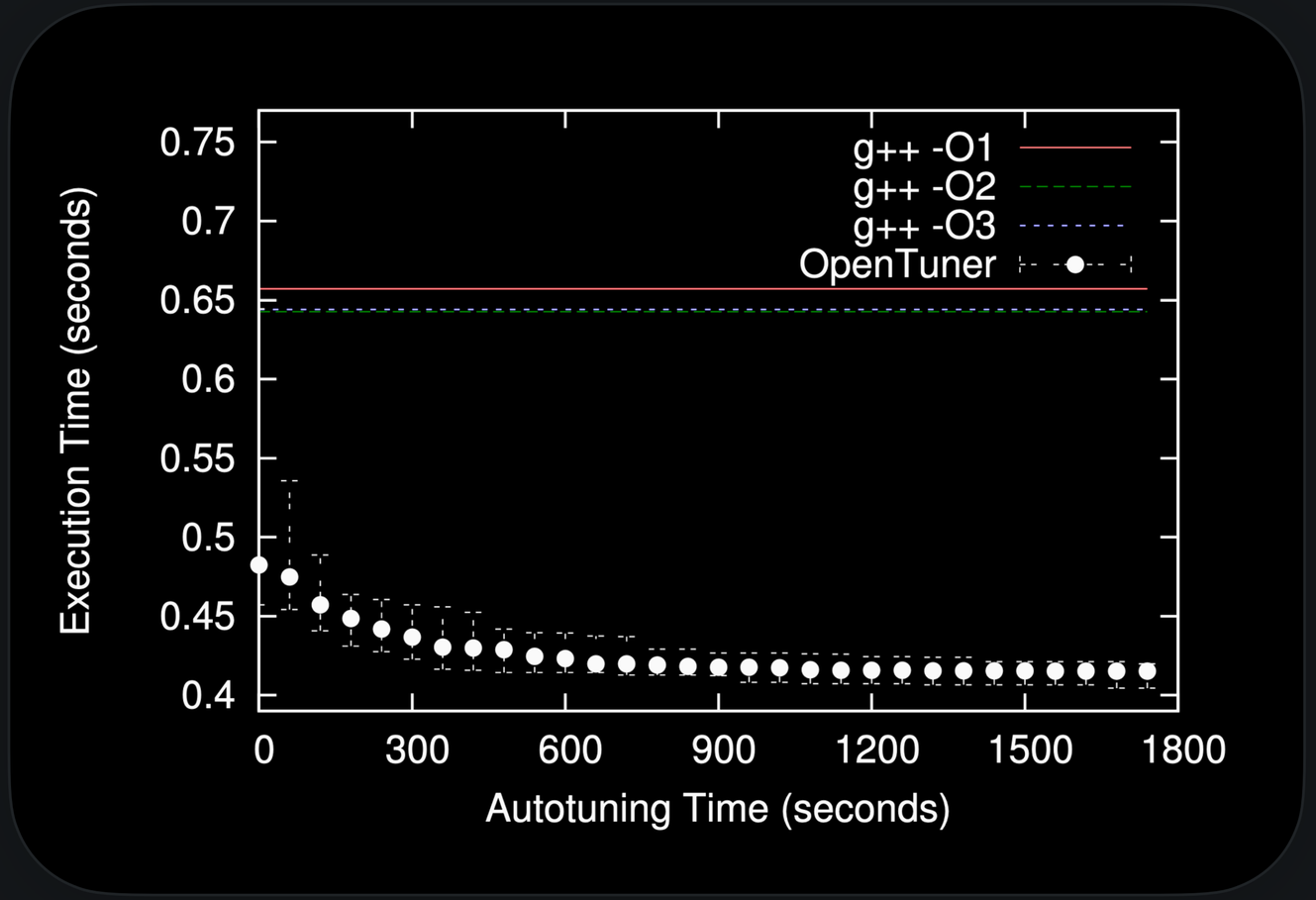
Experiment – GCC Flags

CONFIGURATION

Compiler flags

OBJECTIVE

⏱ Execution Time



Evaluation

Experiment – GCC Flags

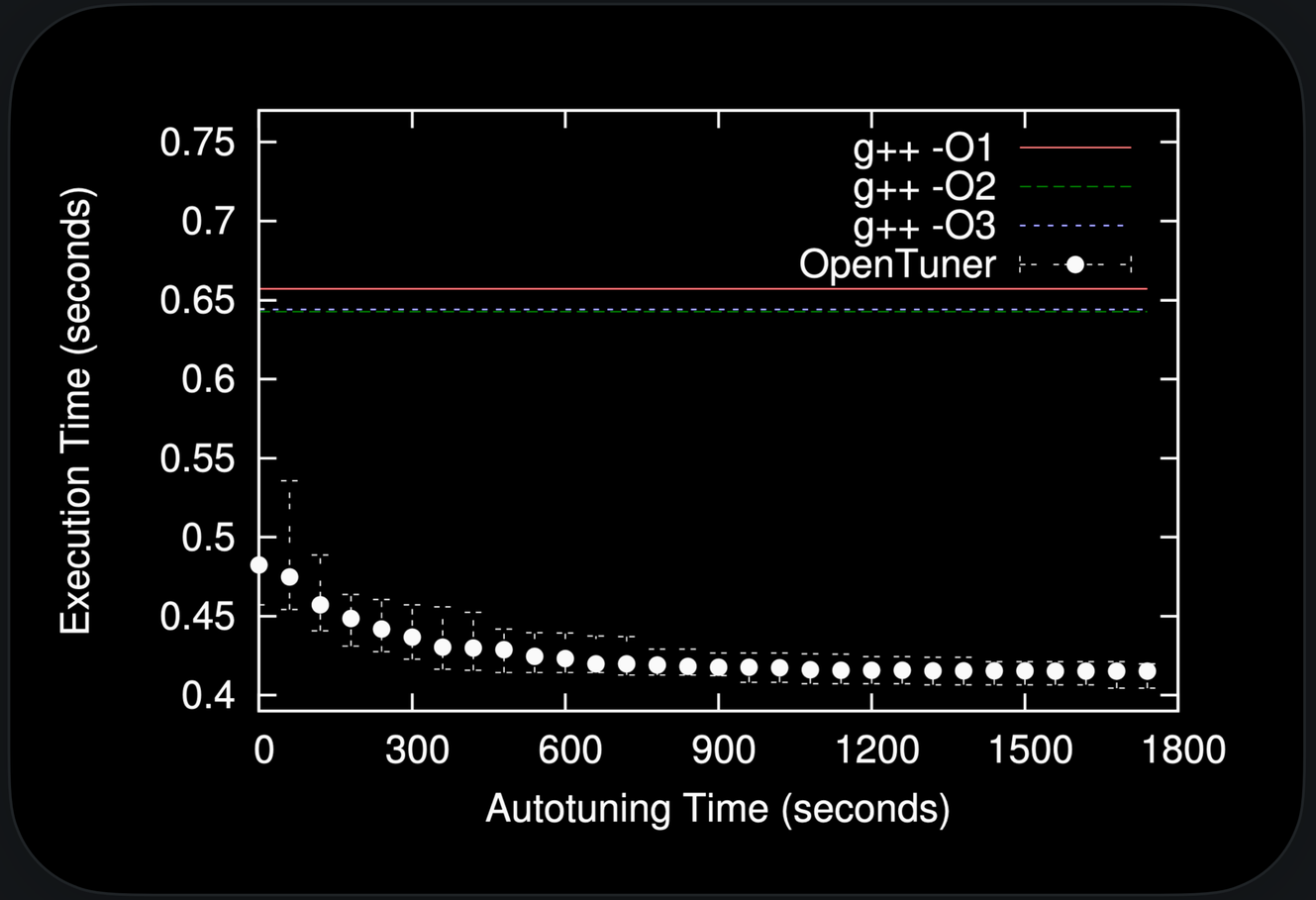
CONFIGURATION

Compiler flags

OBJECTIVE

⏱ Execution Time

RESULTS



Evaluation

Experiment – GCC Flags

CONFIGURATION

Compiler flags

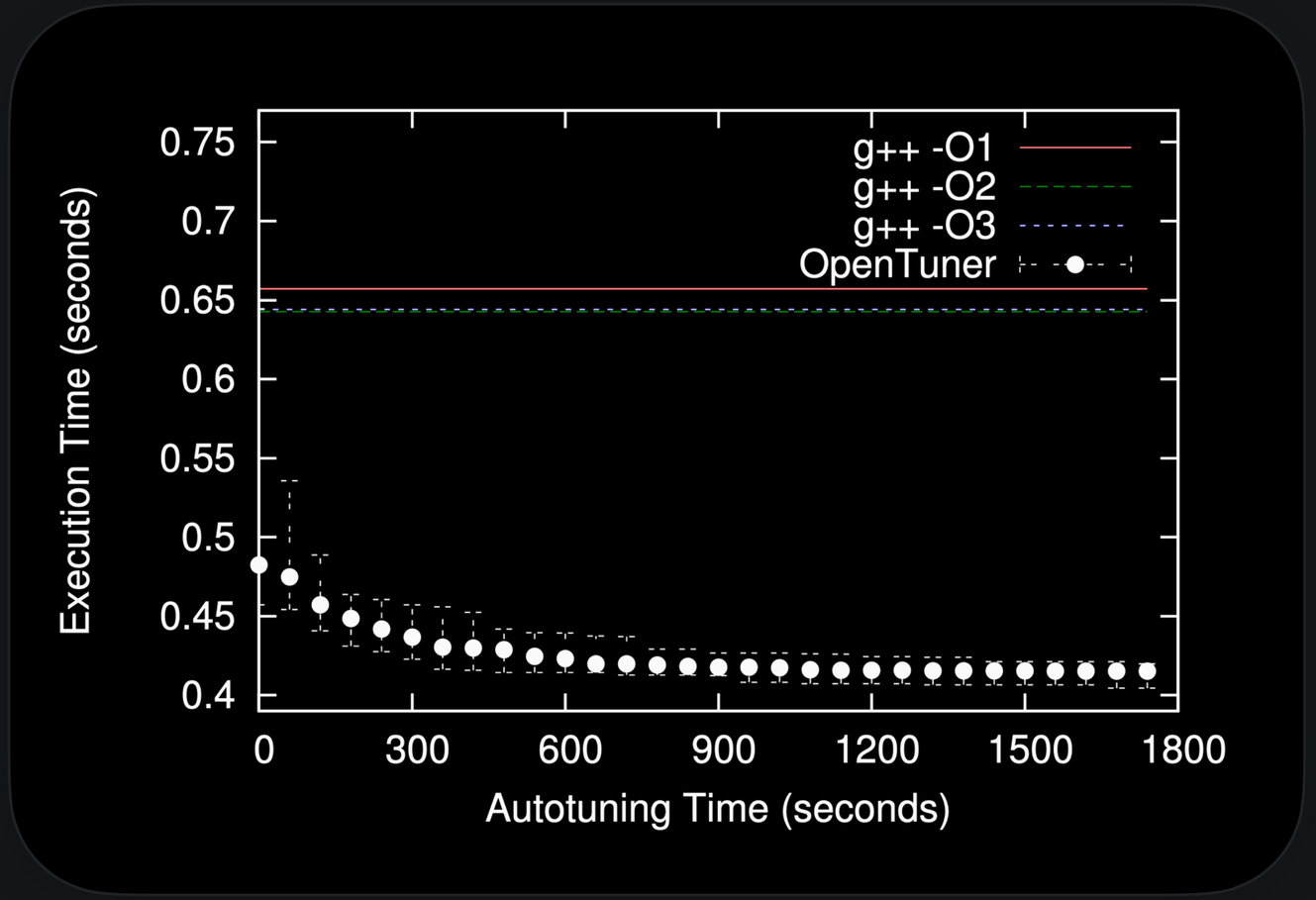
OBJECTIVE

⏱ Execution Time

RESULTS

Raytracing

≈ −30%



Evaluation

Experiment – GCC Flags

CONFIGURATION

Compiler flags

OBJECTIVE

⏱ Execution Time

RESULTS

Raytracing

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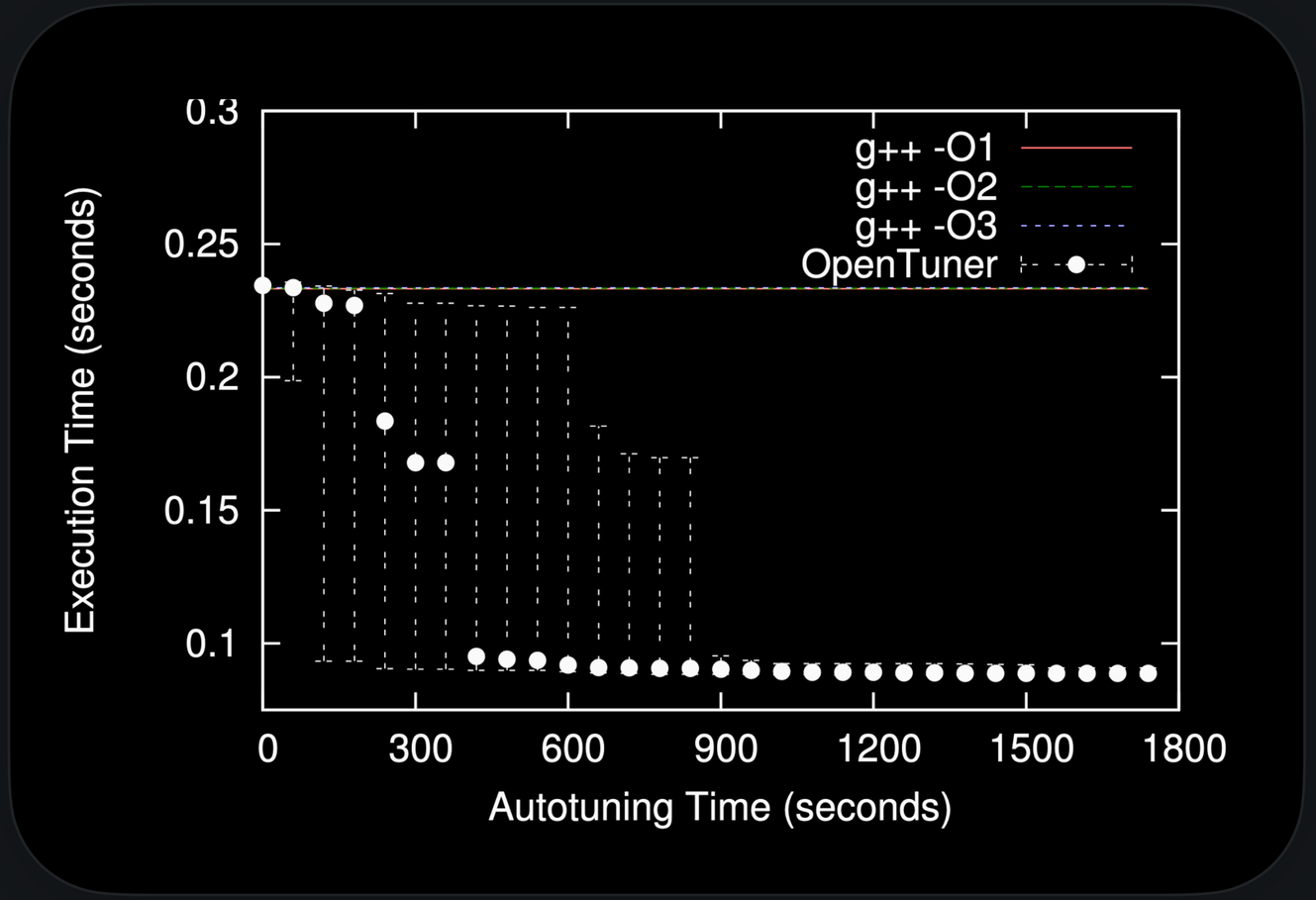


Evaluation

Experiment – GCC Flags

CONFIGURATION

Compiler flags

OBJECTIVE

⏱ Execution Time

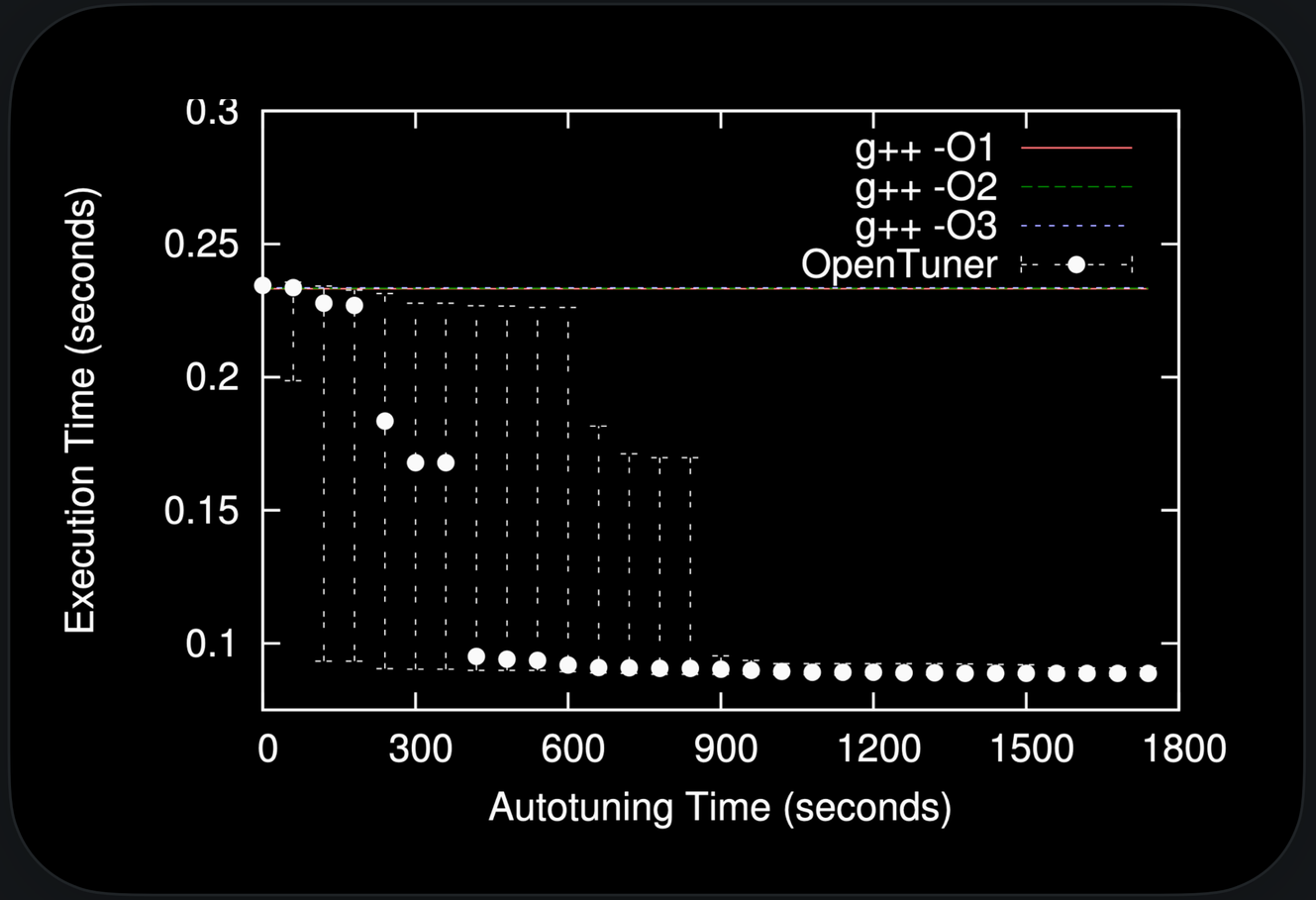
RESULTS

Raytracing

≈ −30%

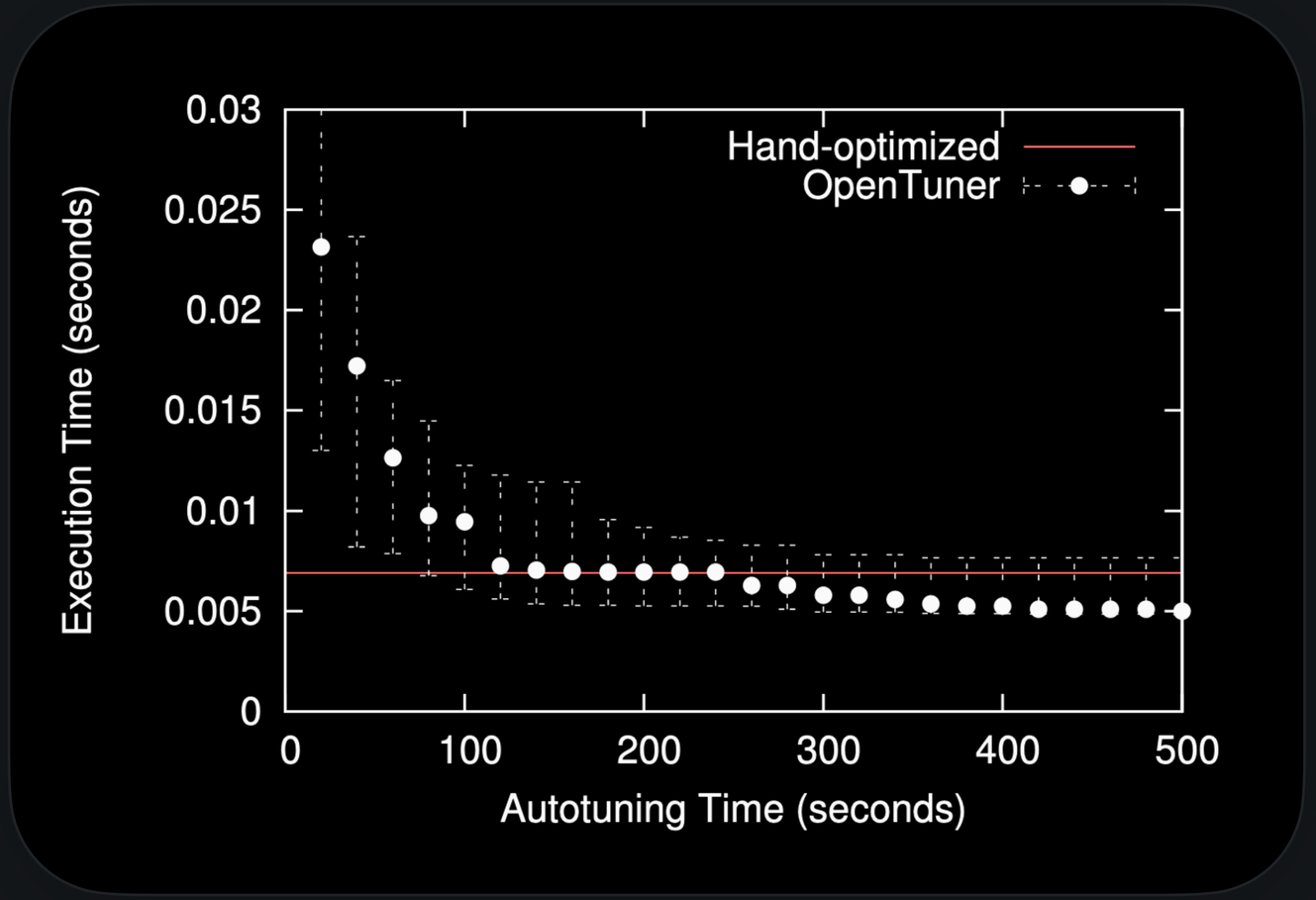
Matrix Multiplication

≈ −60%



Evaluation

Experiment – Halide Graphics Processing Pipeline Schedule



Evaluation

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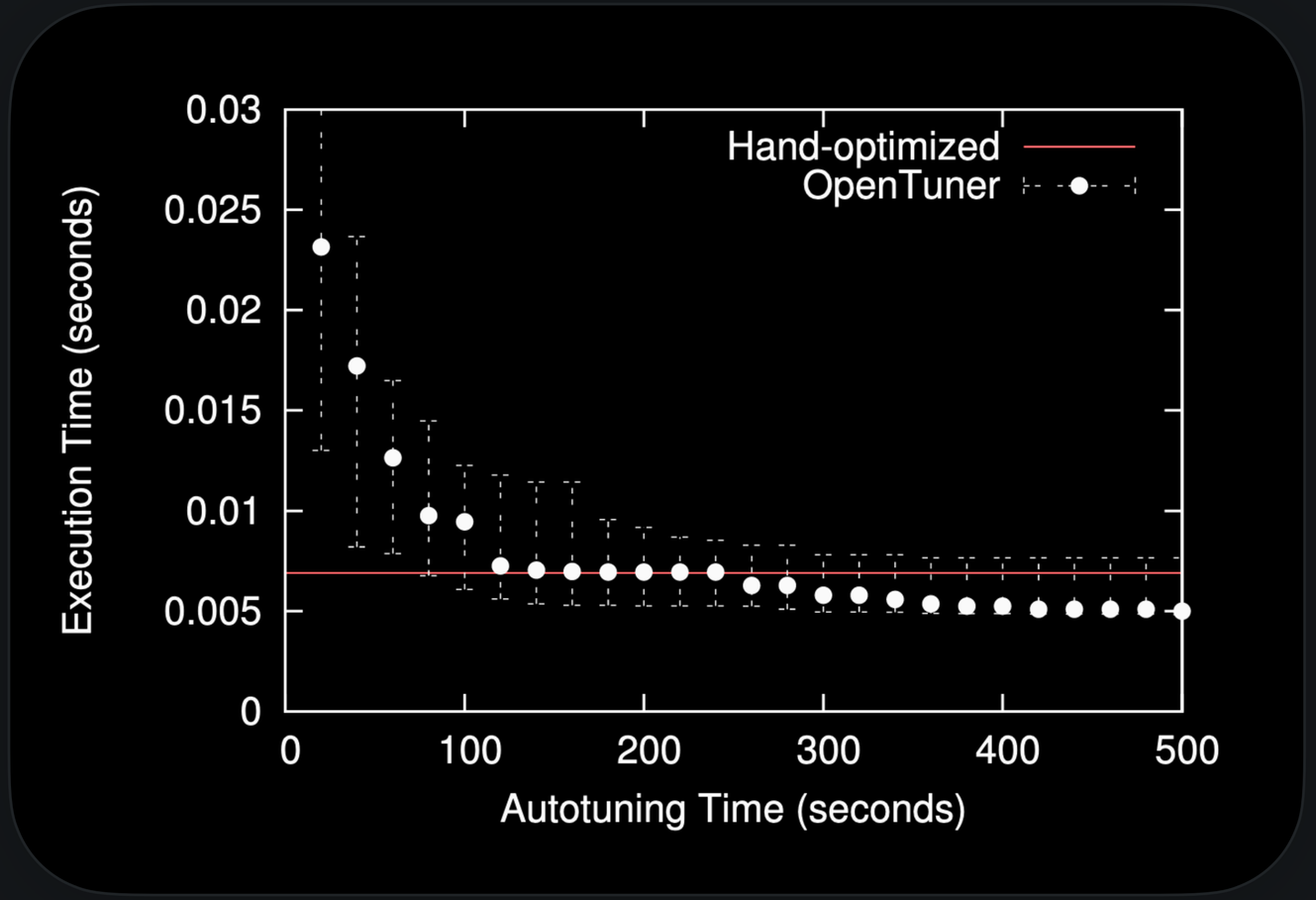

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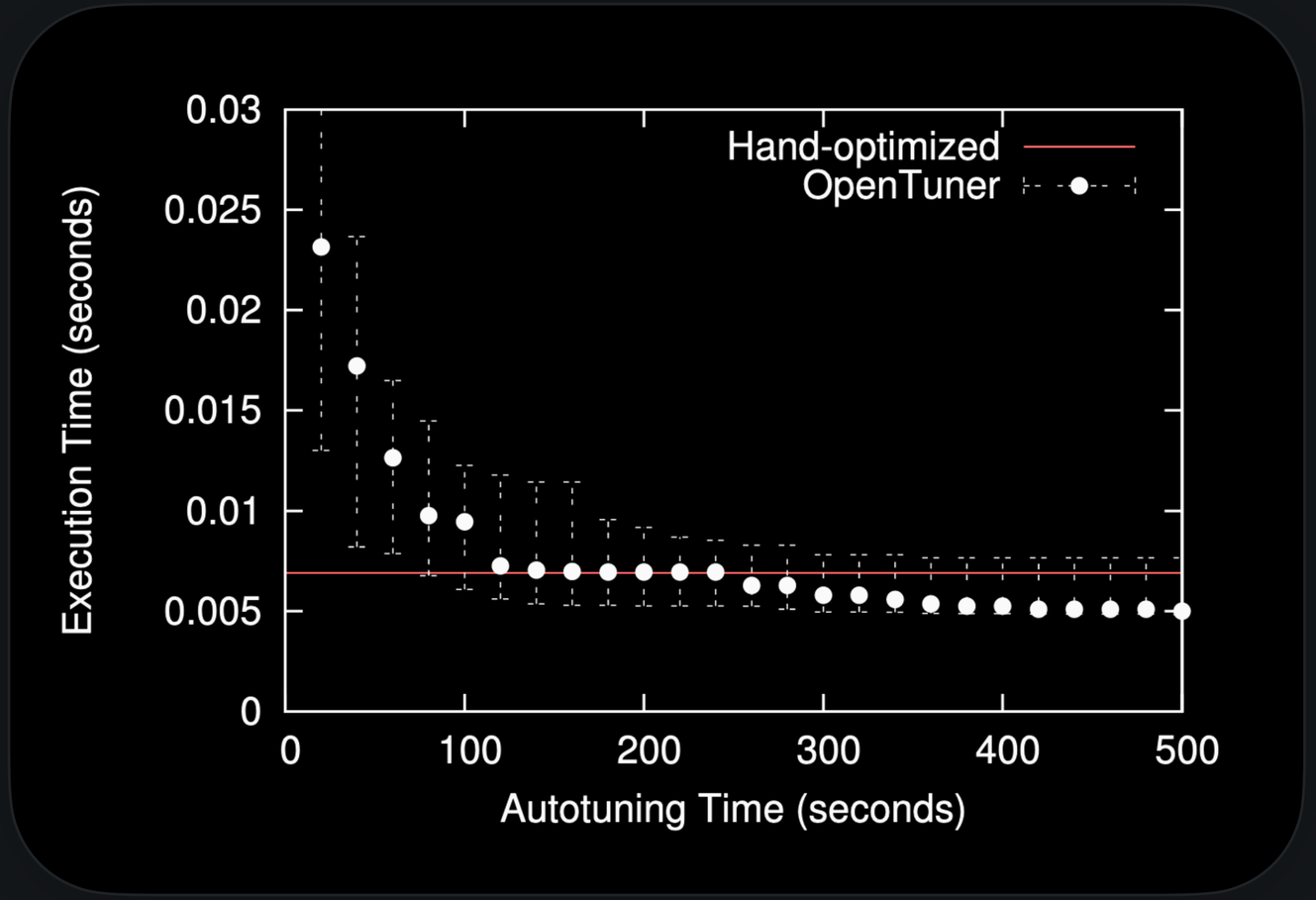
Experiment – Halide Graphics Processing Pipeline Schedule

CONFIGURATION

Pipeline schedule order



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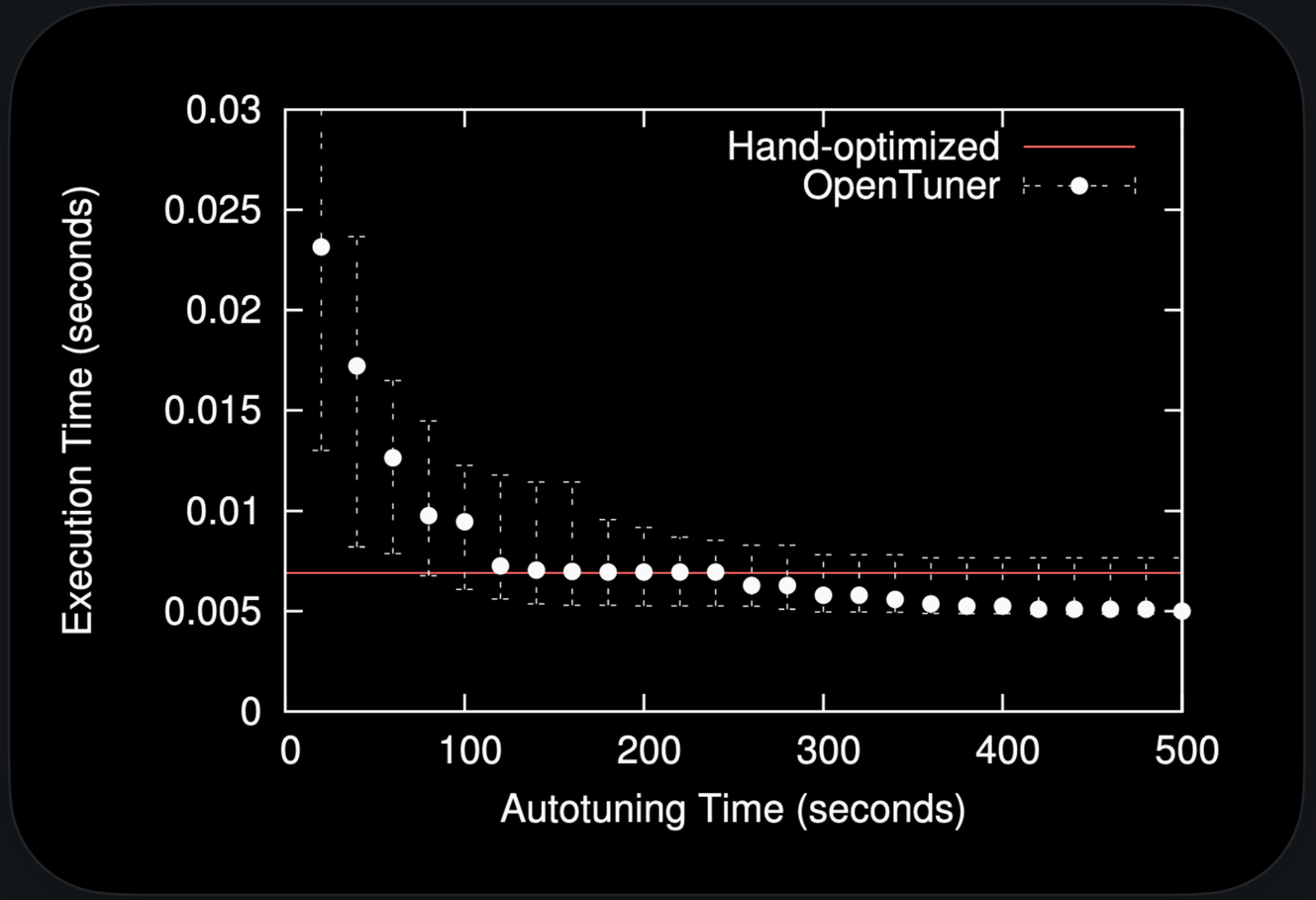

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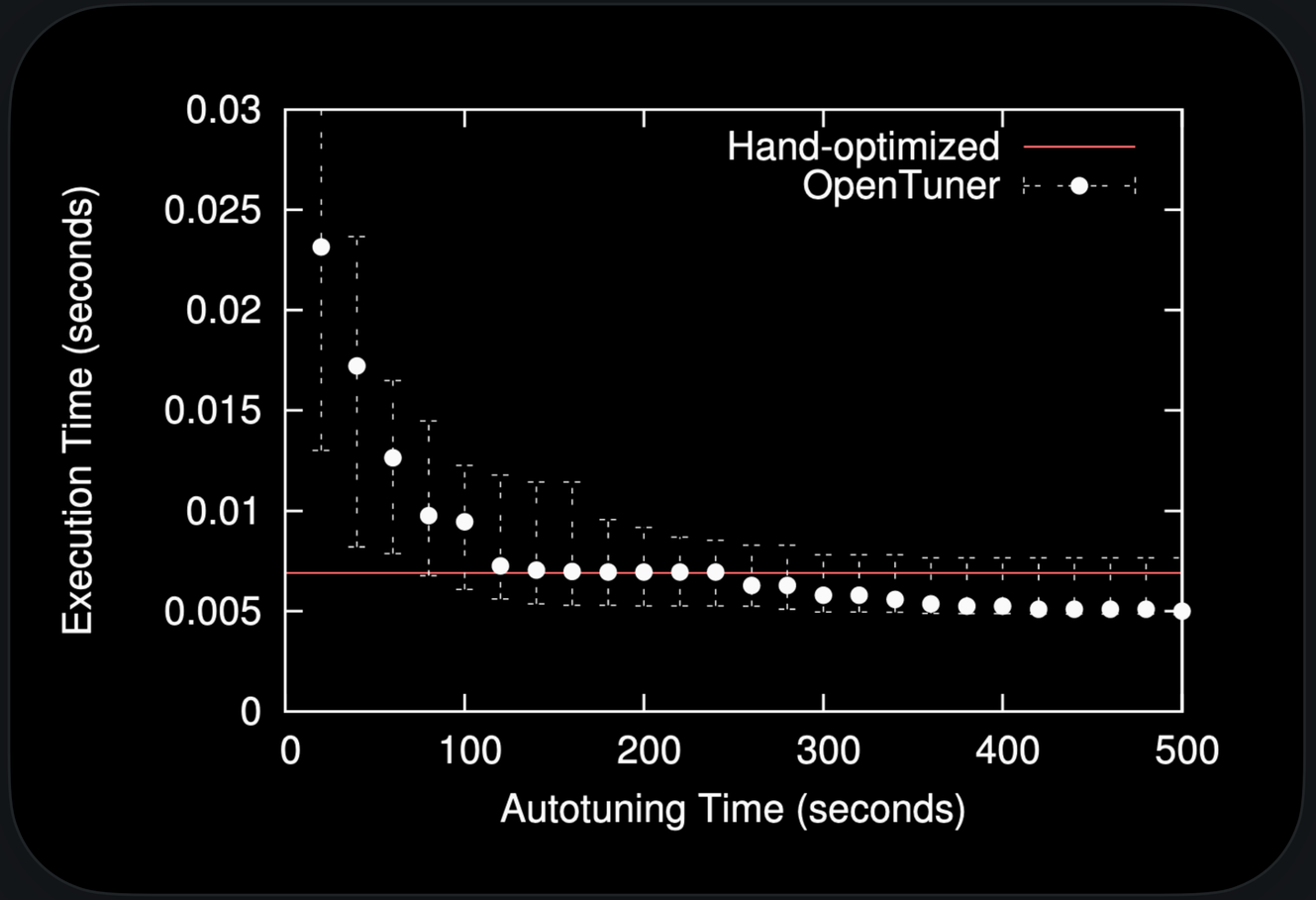


Evaluation

Experiment – Halide Graphics Processing Pipeline Schedule

CONFIGURATION

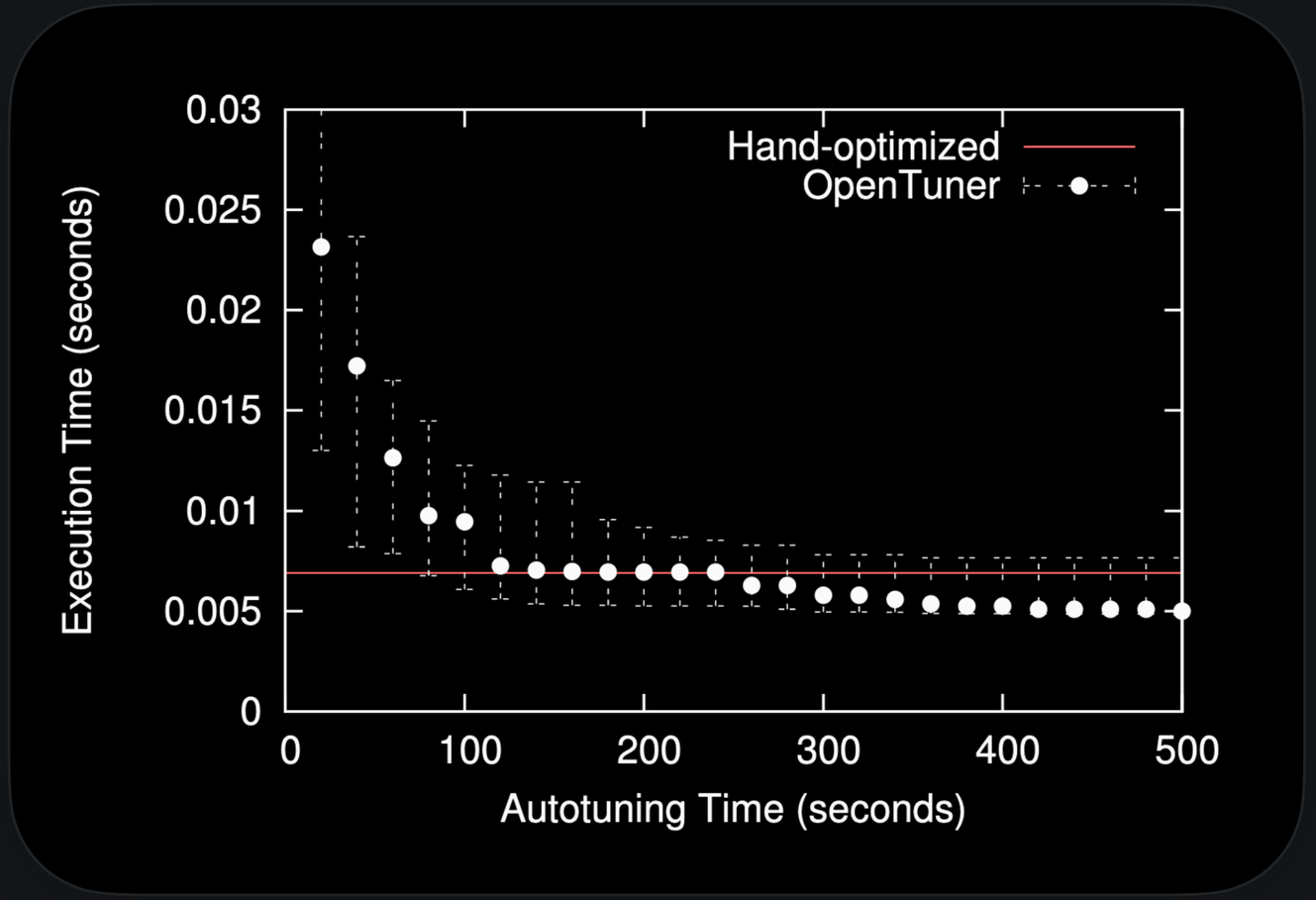
Pipeline schedule order

OBJECTIVE

⏱ Execution Time

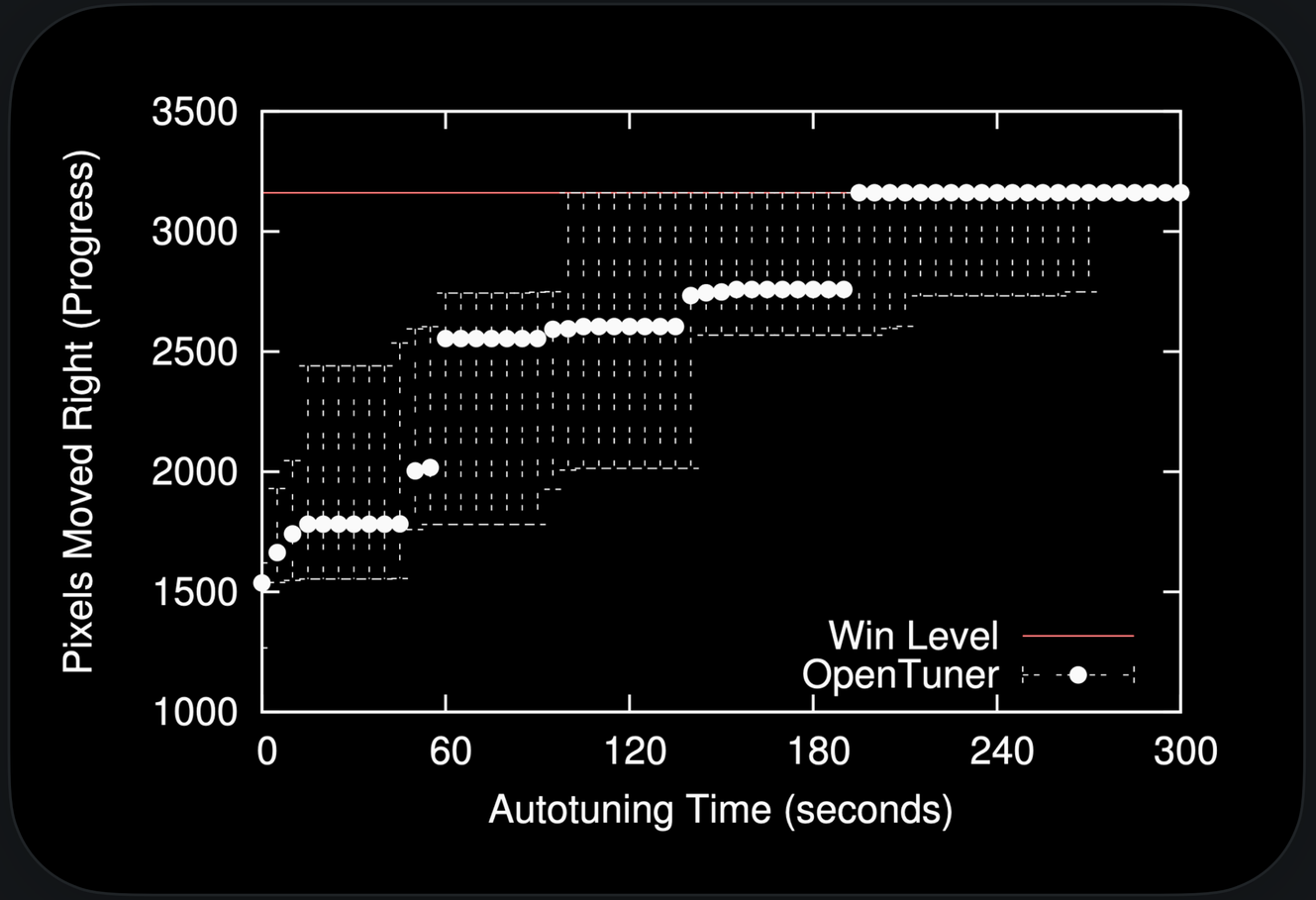
RESULTS

Blur Pipeline
reaches hand-optimized performance



Evaluation

Experiment – Super Mario Bros.



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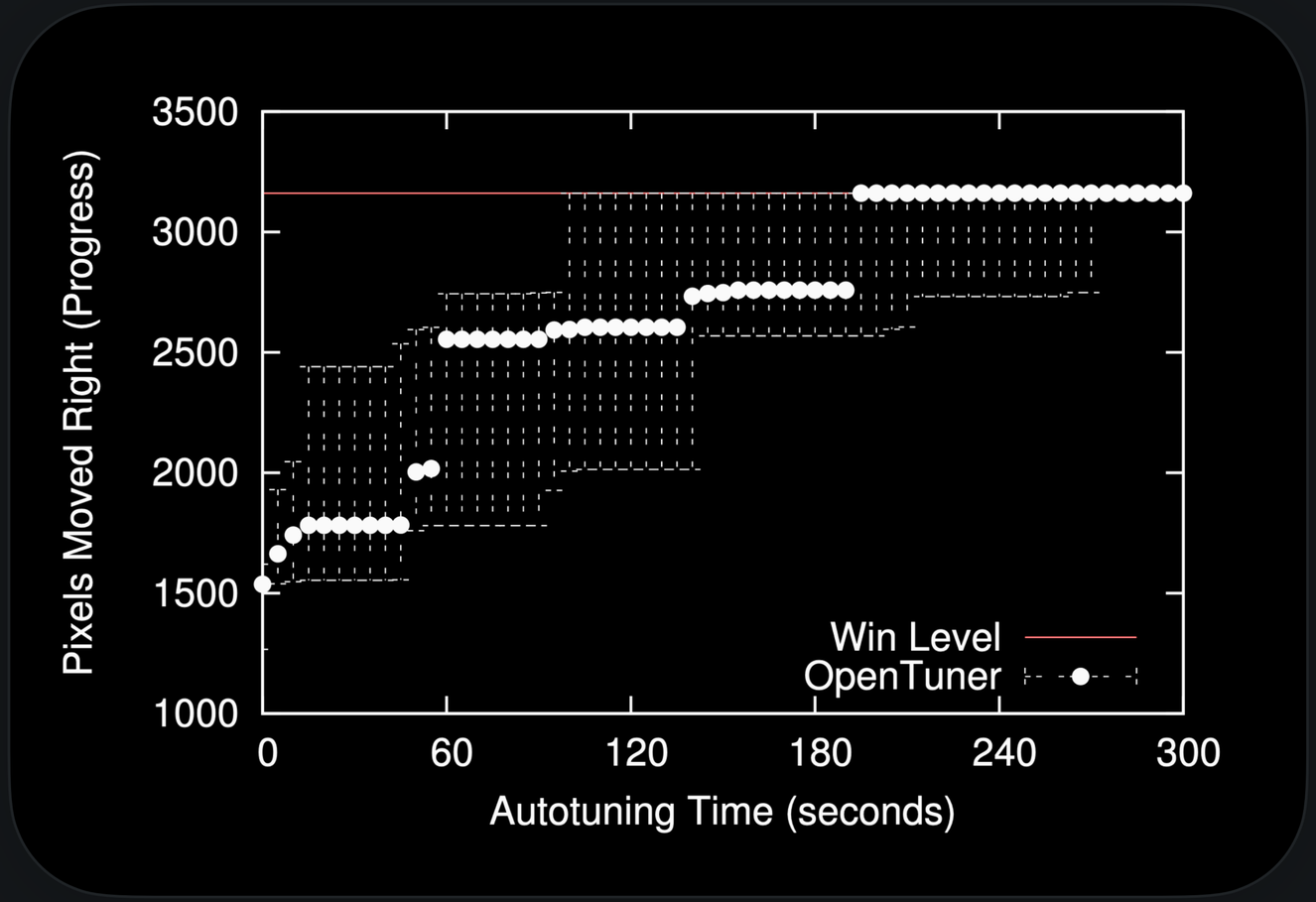
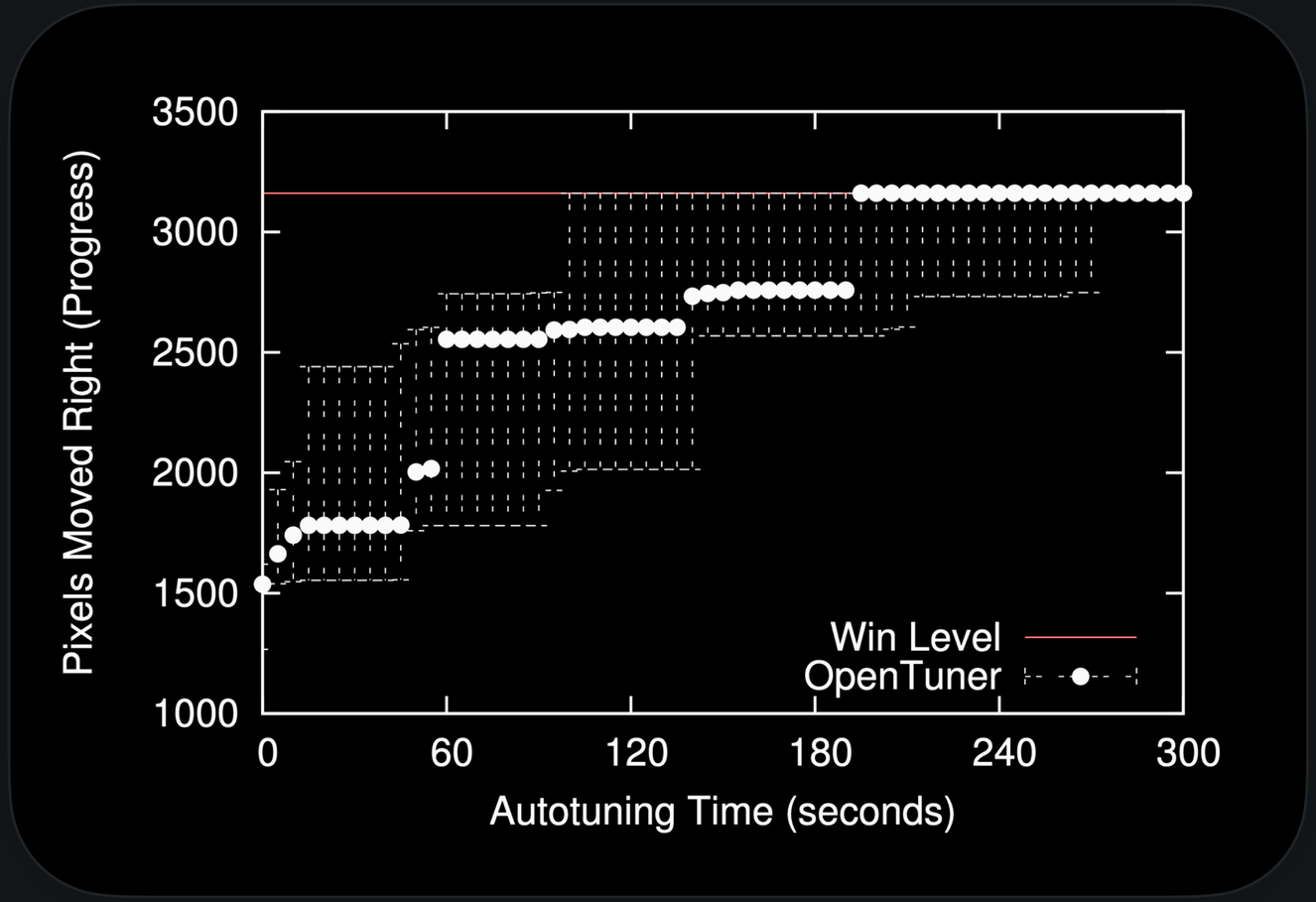


Evaluation

Experiment – Super Mario Bros.

CONFIGURATION

Sequence of button presses



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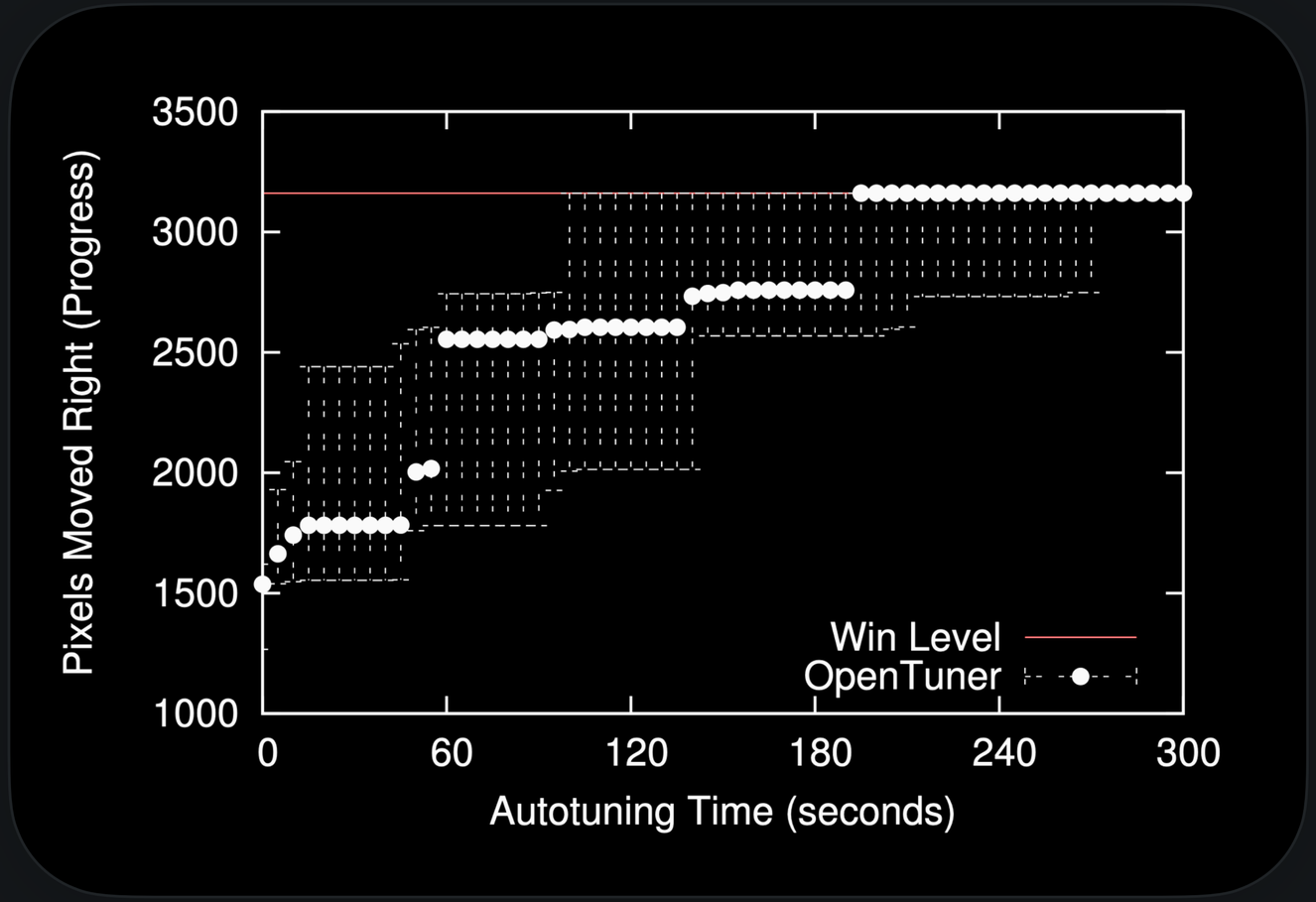

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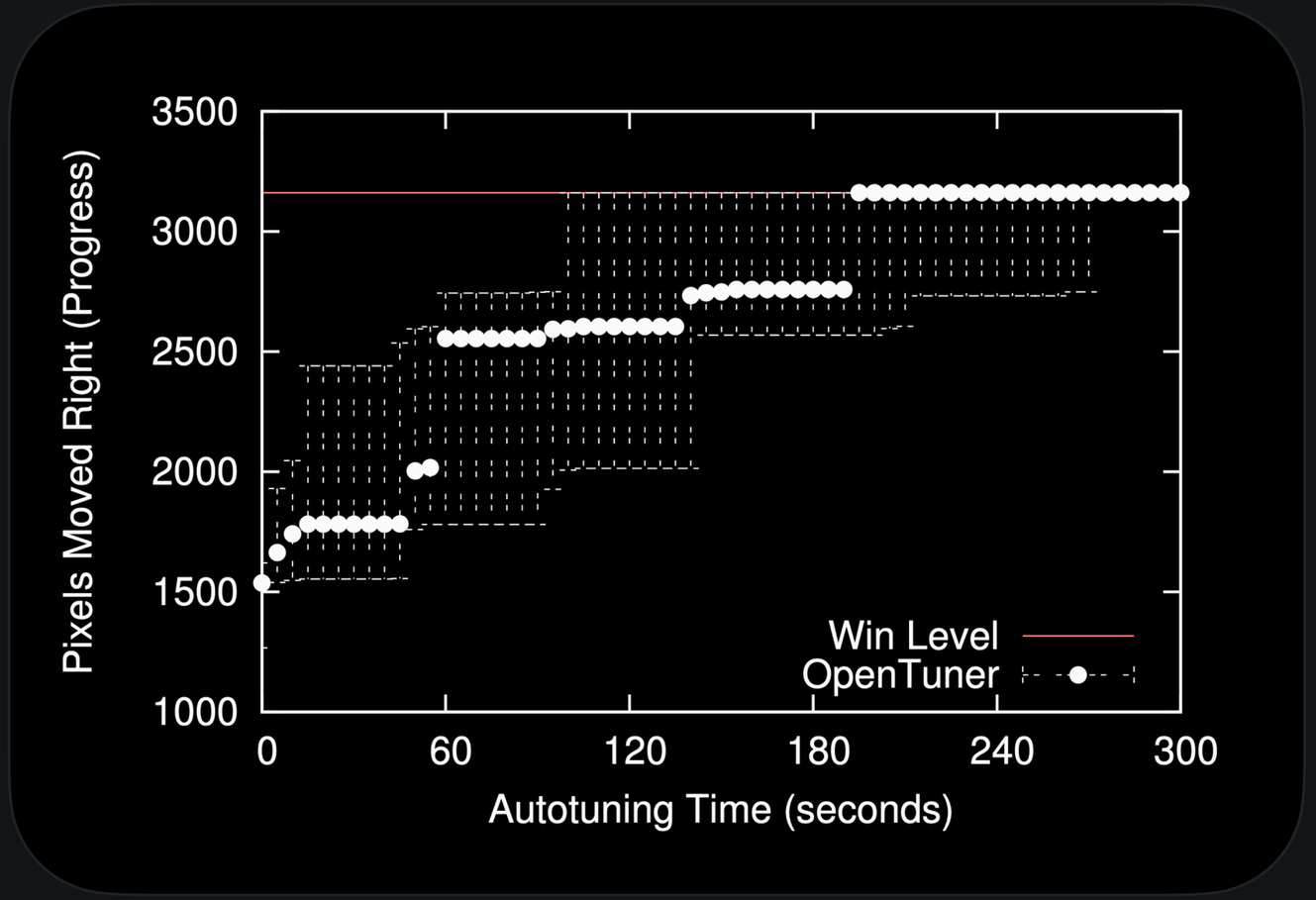
🏅 Execution Time



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CONFIGURATION

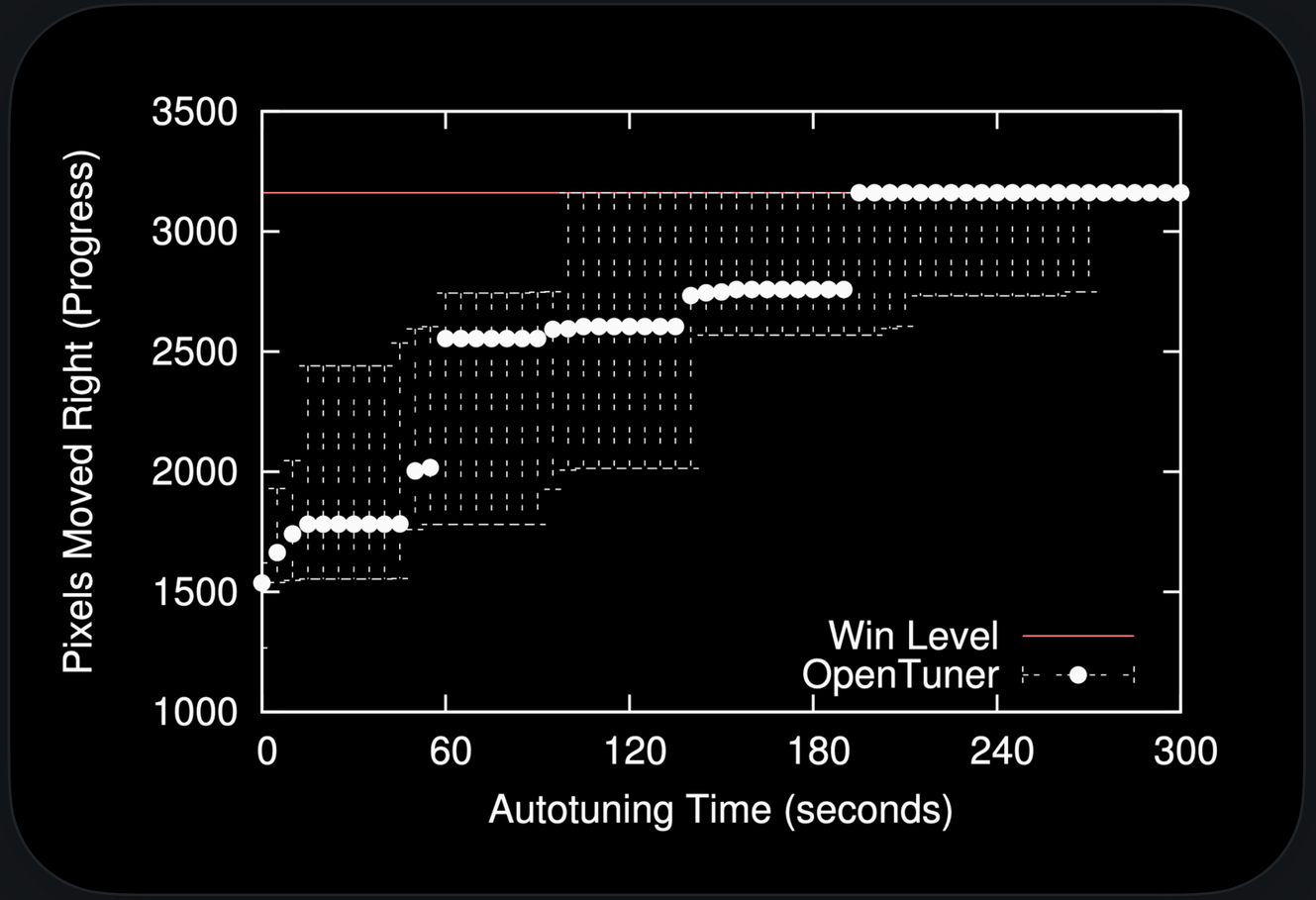
Sequence of button presses

OBJECTIVE

🏅 Execution Time

RESULTS

Successful coordination of jump: right moment, duration, speed, return on pit



Conclusions

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Conclusions

Motivated by *PetaBricks*[28]

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Configuration representation + search techniques
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Multiple concurrent search techniques

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- Multiple concurrent search techniques
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FOSS software

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FOSS software

→ **Portable autotuner**

Thoughts...

[7] V. Dalibard, M. Schaarschmidt, and E. Yoneki: BOAT: Building Auto-Tuners with Structured Bayesian Optimization, WWW, 2017.
[32] S. Cereda, S. Valladares, P. Cremonesi and S. Doni: CGPTuner: a Contextual Gaussian Process Bandit Approach for the Automatic Tuning IT Configurations Under Varying Workload Conditions, VLDB, 2021.

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- Extensibility + Abstractions

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- Extensibility + Abstractions
- Portability from domain-agnostic design

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[32] S. Cereda, S. Valladares, P. Cremonesi and S. Doni: CGPTuner: a Contextual Gaussian Process Bandit Approach for the Automatic Tuning IT Configurations Under Varying Workload Conditions, VLDB, 2021.

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OpenTuner

An Extensible Framework for Program Autotuning

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