Search Based Software Engineering
SBSE

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Thanks for slides

Yue Jia, CREST

Spiros Mancoridis, Drexel

Shin Yoo, CREST

Joachim Wegener, B&M

Yuanyuan Zhang, CREST

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Overview

Context

What is SBSE? Why should I care?

Examples

Pointers to literature

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Scientists' and Engineers' viewpoints

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Scientists' and Engineers' viewpoints

scientist:

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Scientists' and Engineers' viewpoints

scientist:

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Scientists' and Engineers' viewpoints

scientist:

what is true

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Scientists' and Engineers' viewpoints

scientist:

what is true
correctness

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Scientists' and Engineers' viewpoints

scientist:

what is true
correctness
model the world

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Scientists' and Engineers' viewpoints

scientist:

what is true
correctness
model the world
to understand

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Scientists' and Engineers' viewpoints

scientist:

what is true
correctness
model the world
to understand

engineer:

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Scientists' and Engineers' viewpoints

scientist:

what is true

correctness

model the world

to understand

engineer:

what is possible

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Scientists' and Engineers' viewpoints

scientist:

what is true

correctness

model the world

to understand

engineer:

what is possible

within tolerance

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Scientists' and Engineers' viewpoints

scientist:

what is true

correctness

model the world

to understand

engineer:

what is possible

within tolerance

model the world

Scientists' and Engineers' viewpoints

scientist:

what is true
correctness
model the world
to understand

engineer:

what is possible
within tolerance
model the world
to manipulate

Scientists' and Engineers' viewpoints

computer scientist:

what is true
about computation

prove correctness
make it perfect

software engineer:

what is possible
with software

test for imperfection
find were to improve

Combining Science and Engineering

prove correctness
make it perfect

test for imperfection
find were to improve

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Combining Science and Engineering

prove correctness
make it perfect

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Combining Science and Engineering

prove correctness
make it perfect

where possible ...

... and where impossible ...

test for imperfection
find were to improve

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Combining Science and Engineering

prove correctness
make it perfect

where possible ...

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test for imperfection
find were to improve

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Software Engineering Problems

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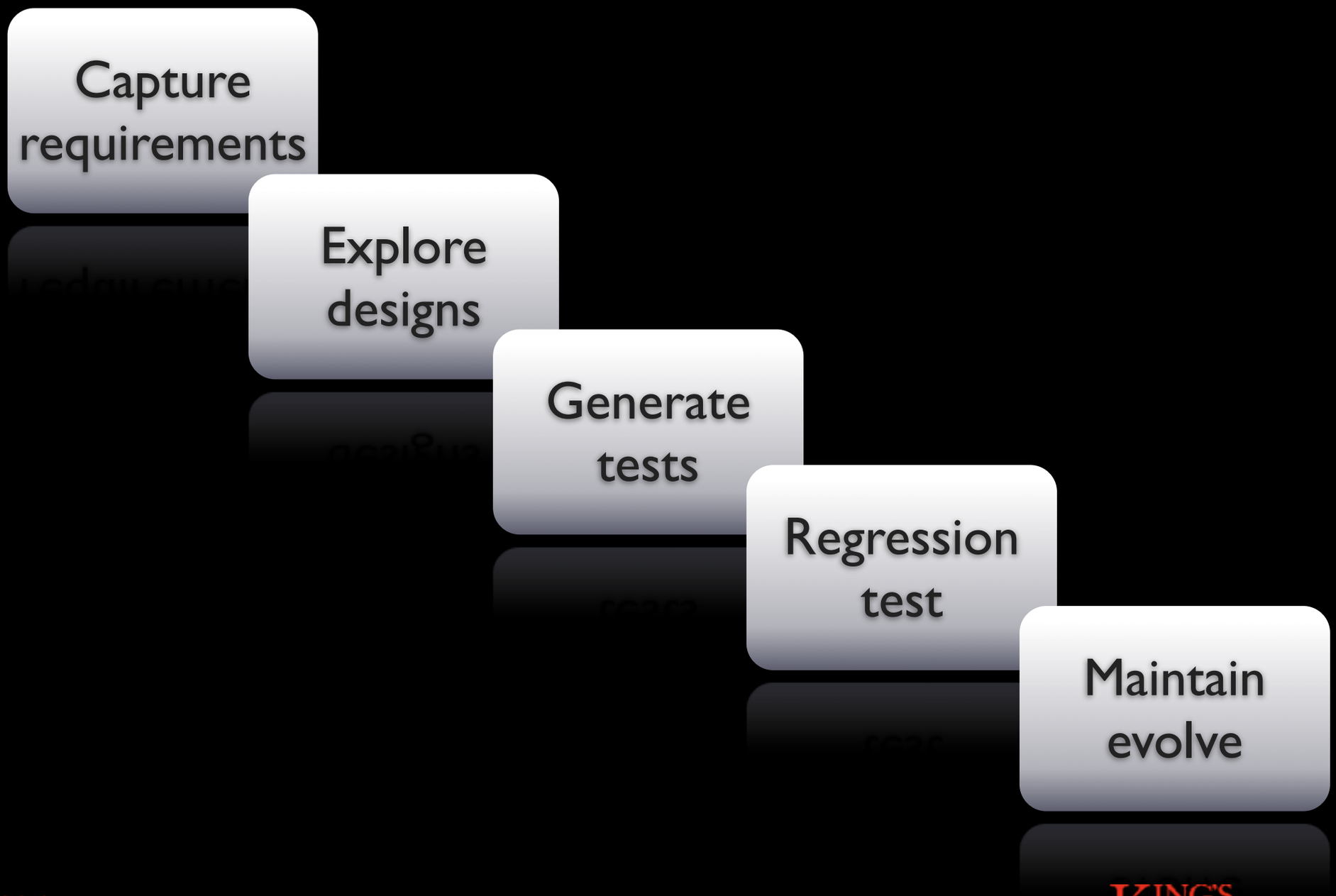
Software Engineering Problems



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Capture requirements

Generate tests

Explore designs

Maintain evolve

Regression test

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Capture requirements

Generate tests

Explore designs

Maintain evolve

Regression test

Minimize

Maximize

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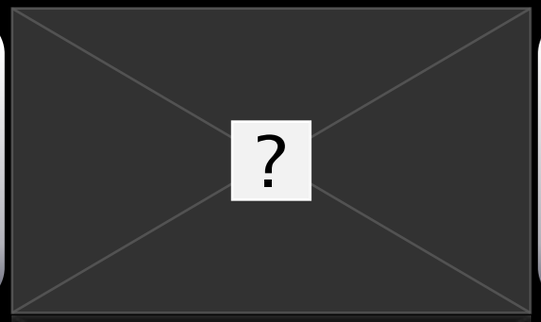

Explore designs

Maintain evolve

Regression test

Minimize

Maximize

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Minimize

Cost
Development time

Maximize

Satisfaction
Fairness

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Capture requirements | Generate tests | Explore designs | Maintain evolve | Regression test

Minimize

Cost
Development time

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Fairness

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Number of tests

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Number of tests
Execution time

Maximize

Fairness

Code coverage

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Minimize

Number of tests
Execution time

Maximize

Code coverage
Test adequacy

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Minimize

Coupling

Maximize

Cohesion

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Coupling

Maximize

Cohesion

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Capture requirements | Generate tests | Explore designs | Maintain evolve | Regression test

Minimize Coupling

Maximize Cohesion

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Capture requirements

Generate tests

Explore designs

Maintain evolve

Regression test

Minimize

Number of tests
Execution time

Maximize

Code coverage
Fault coverage

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Emergent paradigms

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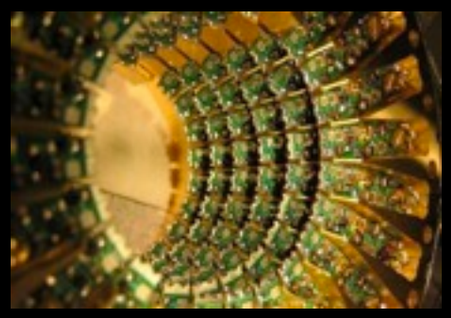
Emergent paradigms

Cloud

Agile

Ambient



Quantum

Non functional properties

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Emergent paradigms

Cloud

Objectives:

distribution

availability

performance

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Emergent paradigms

Cloud

Objectives:

distribution

availability

performance

Jim Larus: Friday's CC Keynote@ETAPS

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Emergent paradigms

Agile

Objectives:

cost
value
refactoring split points

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Emergent paradigms

Ambient

Objectives:

coverage

response

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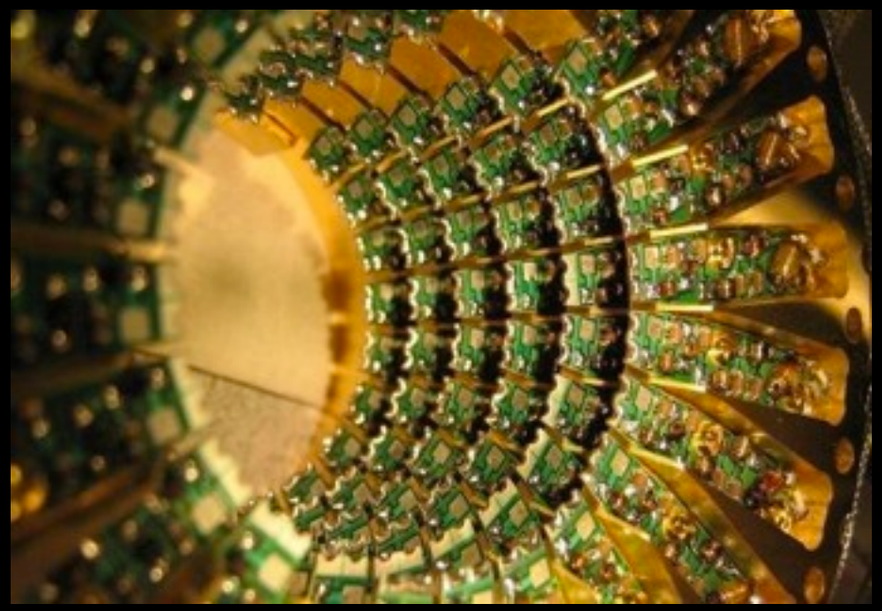
Emergent paradigms

Non functional properties

Objectives:

heat dissipation
WCET
resource use

Emergent paradigms



Quantum

Objectives:

entanglement
functionality

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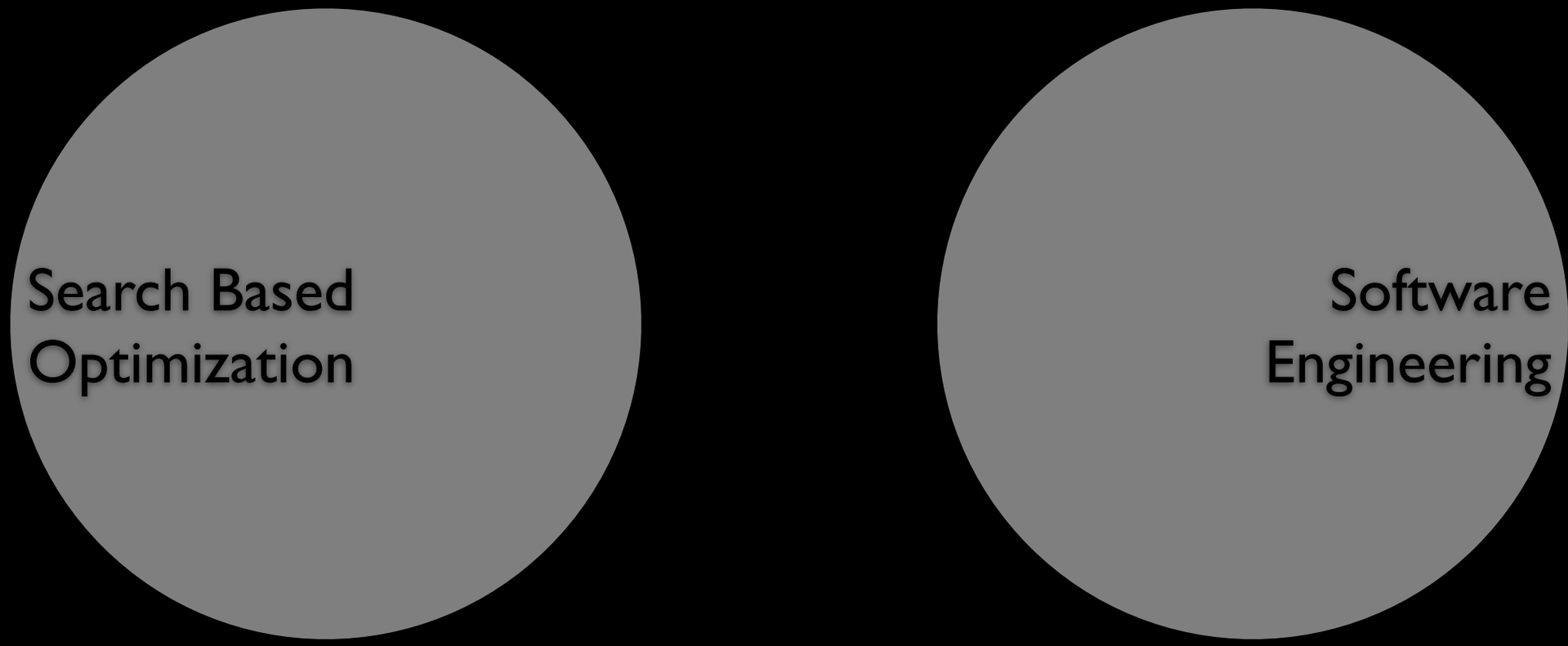
What is SBSE



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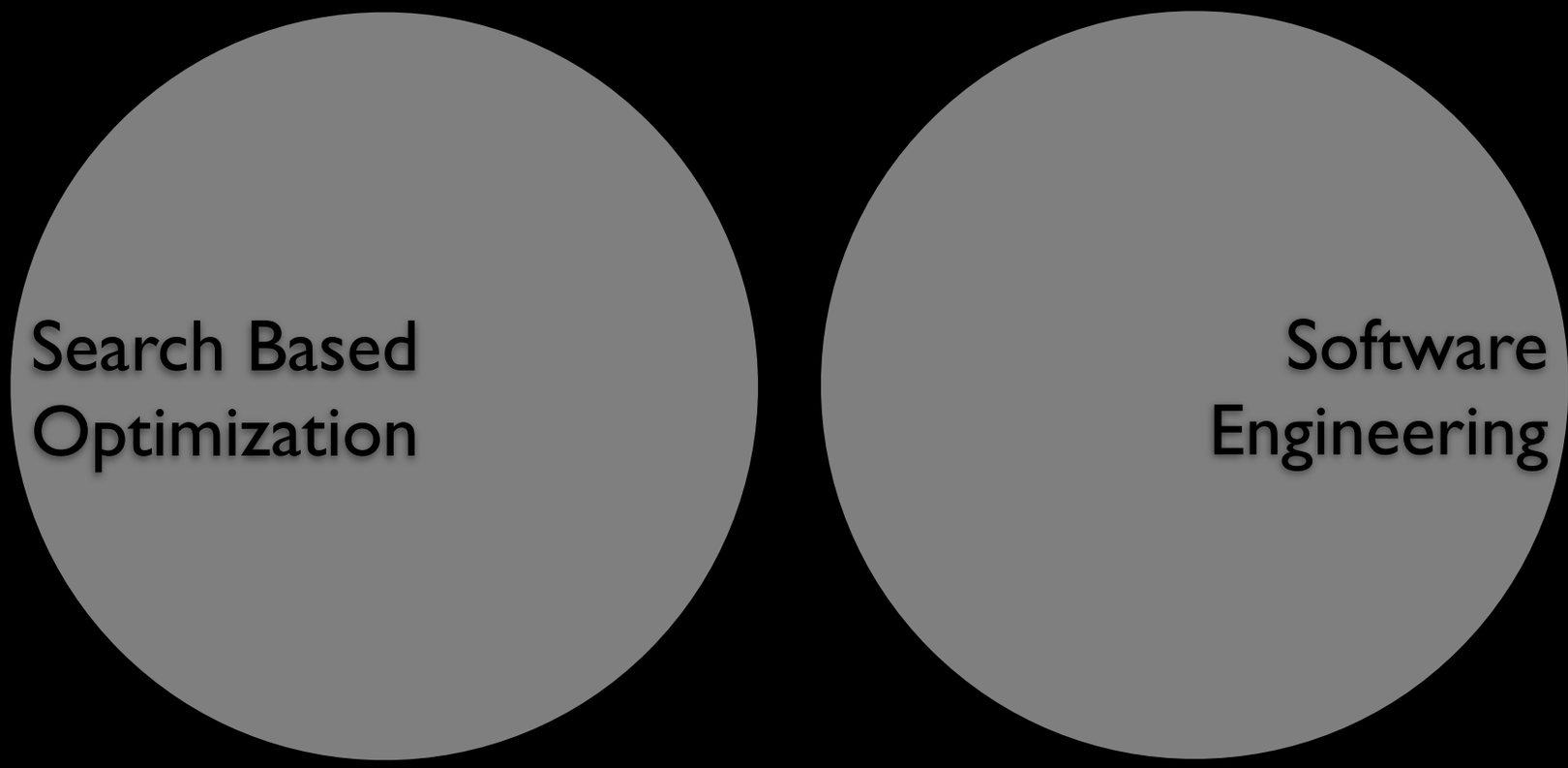
What is SBSE



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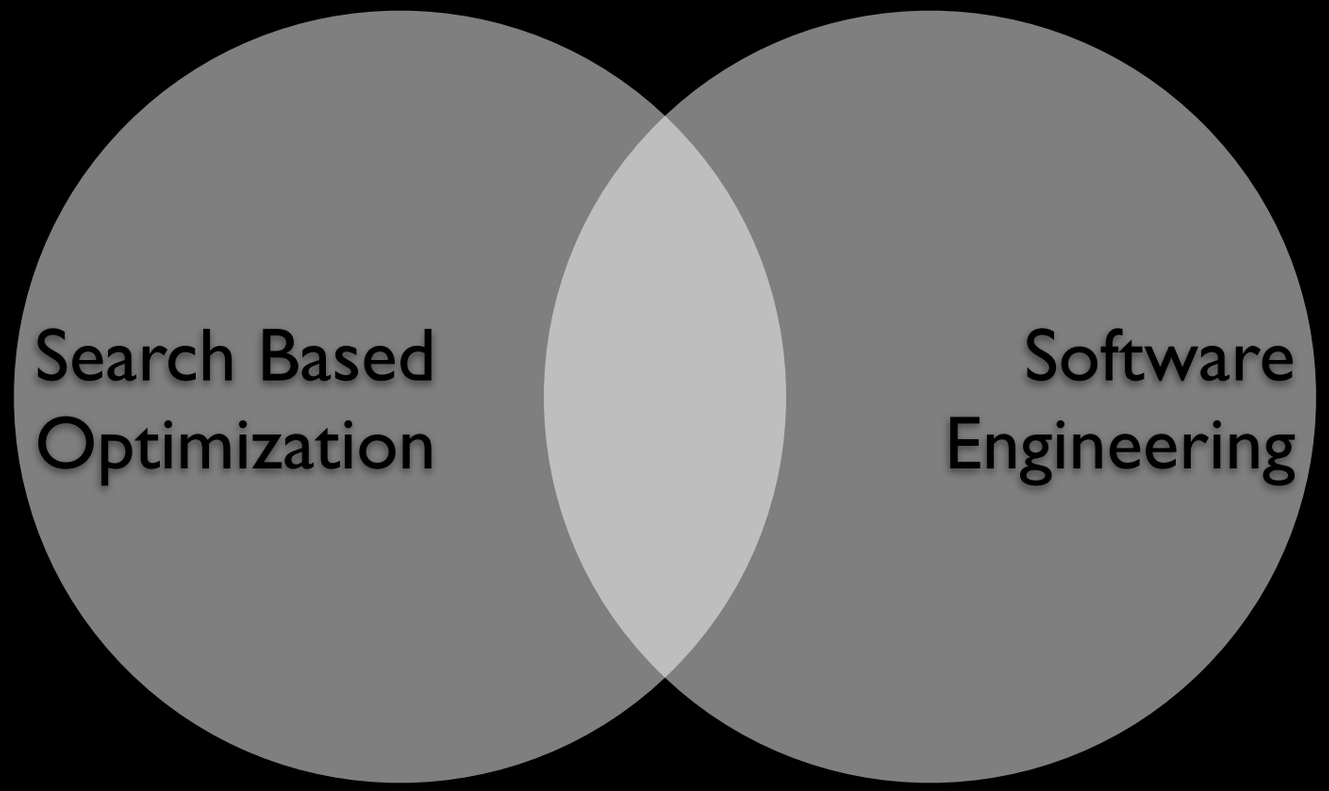

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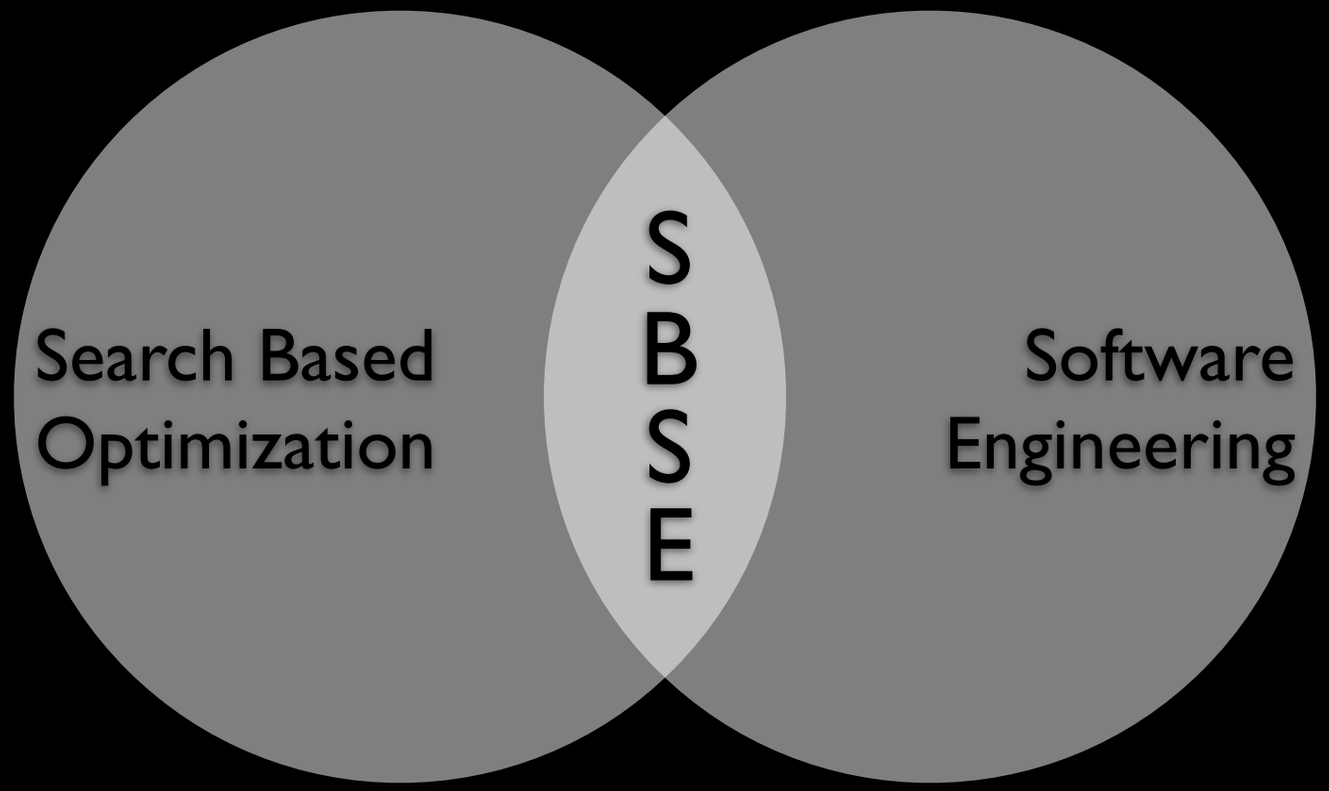

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What is SBSE

In SBSE we apply search techniques to search large search spaces, guided by a fitness function that captures properties of the acceptable software artefacts we seek.

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What is SBSE

In SBSE we apply search techniques to search large search spaces, guided by a fitness function that captures properties of the acceptable software artefacts we seek.

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What is SBSE

In SBSE we apply search techniques to search large search spaces, guided by a fitness function that captures properties of the acceptable software artefacts we seek.

Tabu Search

Ant Colonies

Particle Swarm Optimization

Hill Climbing

Genetic Algorithms

Genetic Programming

Simulated Annealing

Greedy

LP

Random

Estimation of Distribution Algorithms

The advantages of SBSE

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The advantages of SBSE

Insight-rich

Scalable

Robust

Generic

Realistic

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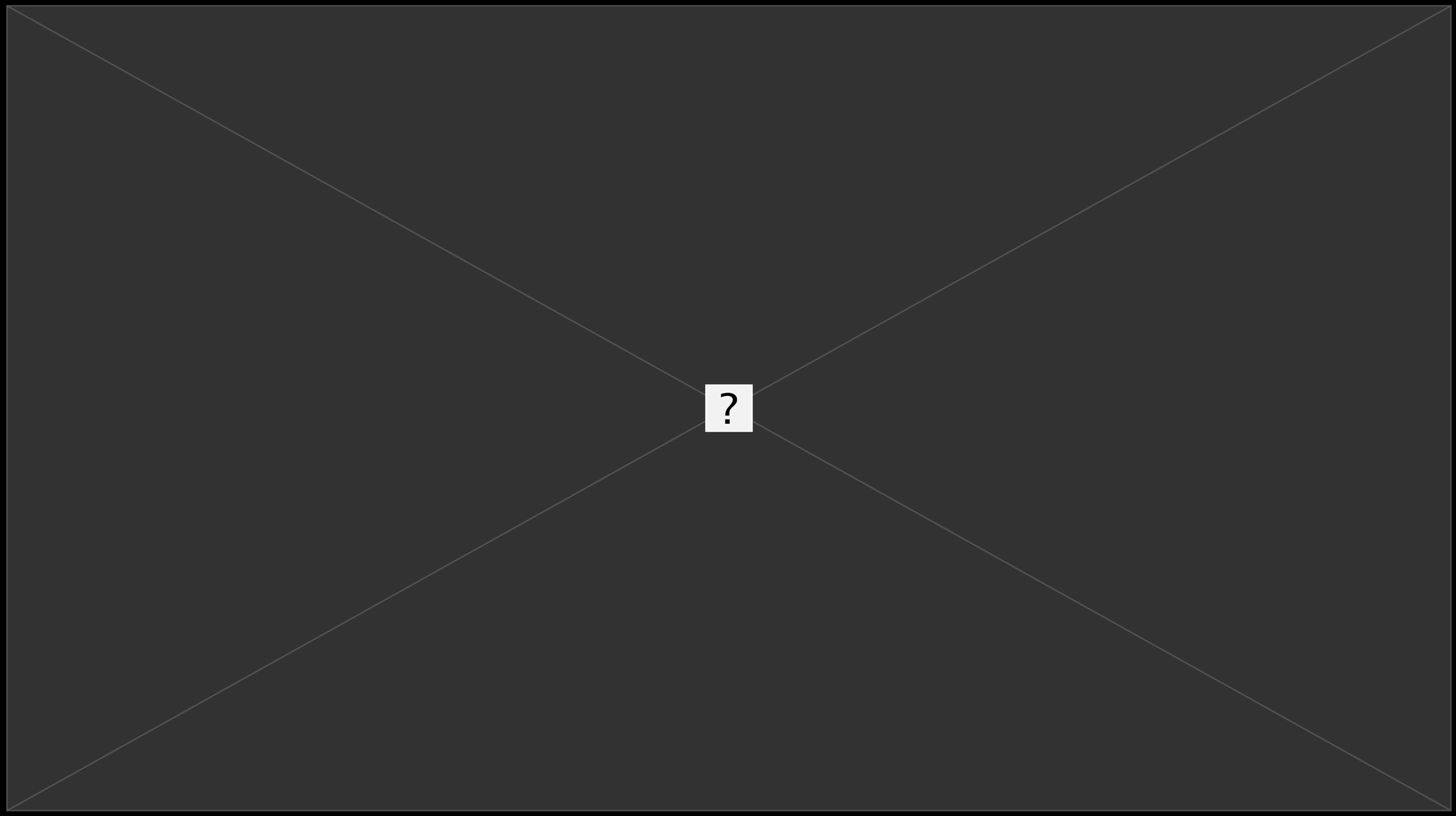

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World Wide Activity

24 countries every continent > 600 papers

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World Wide Activity

24 countries every continent > 600 papers

At ETAPS

Gal Katz and Doron Peled: *Code mutation in verification and automatic code correction*. TACAS, Thursday afternoon.

JunChao Xiao, Leon Osterweil, Qing Wang and MingShu Li: *Dynamic Resource Scheduling in Disruption-Prone Software Development Environments*. FASE, this afternoon

Evolutionary Testing

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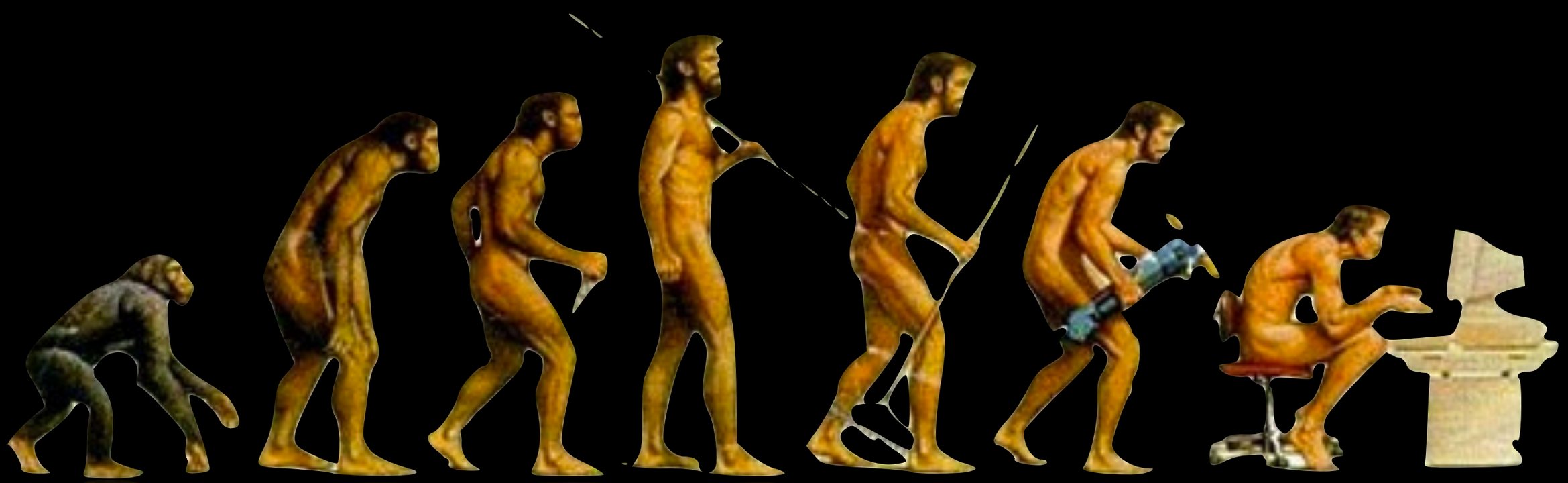
Evolutionary Testing



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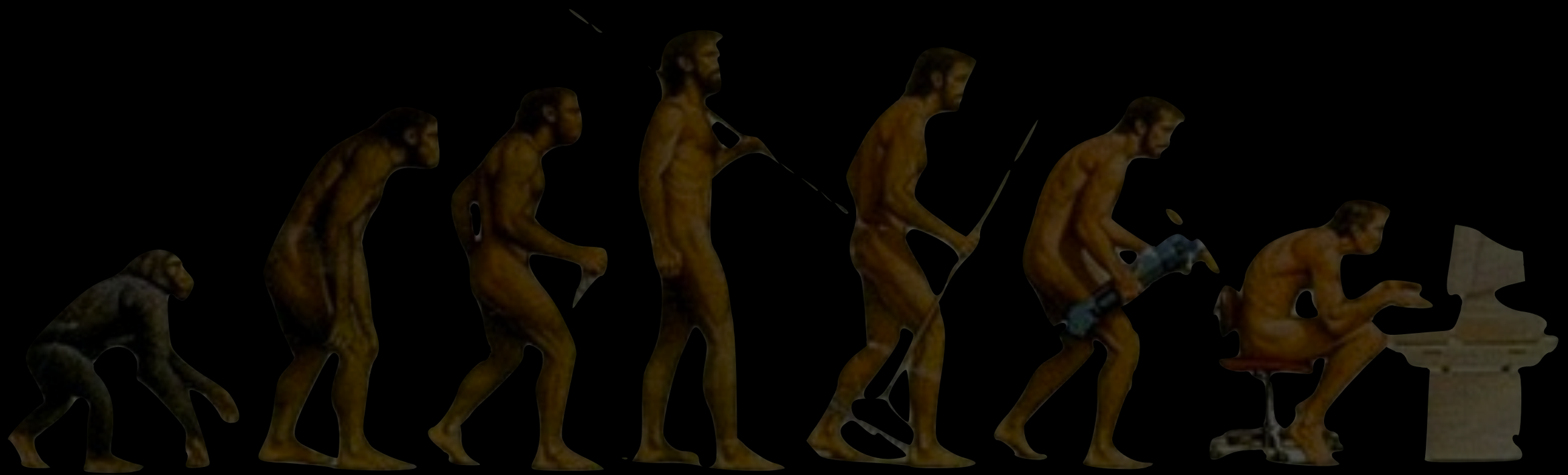
Evolutionary Testing



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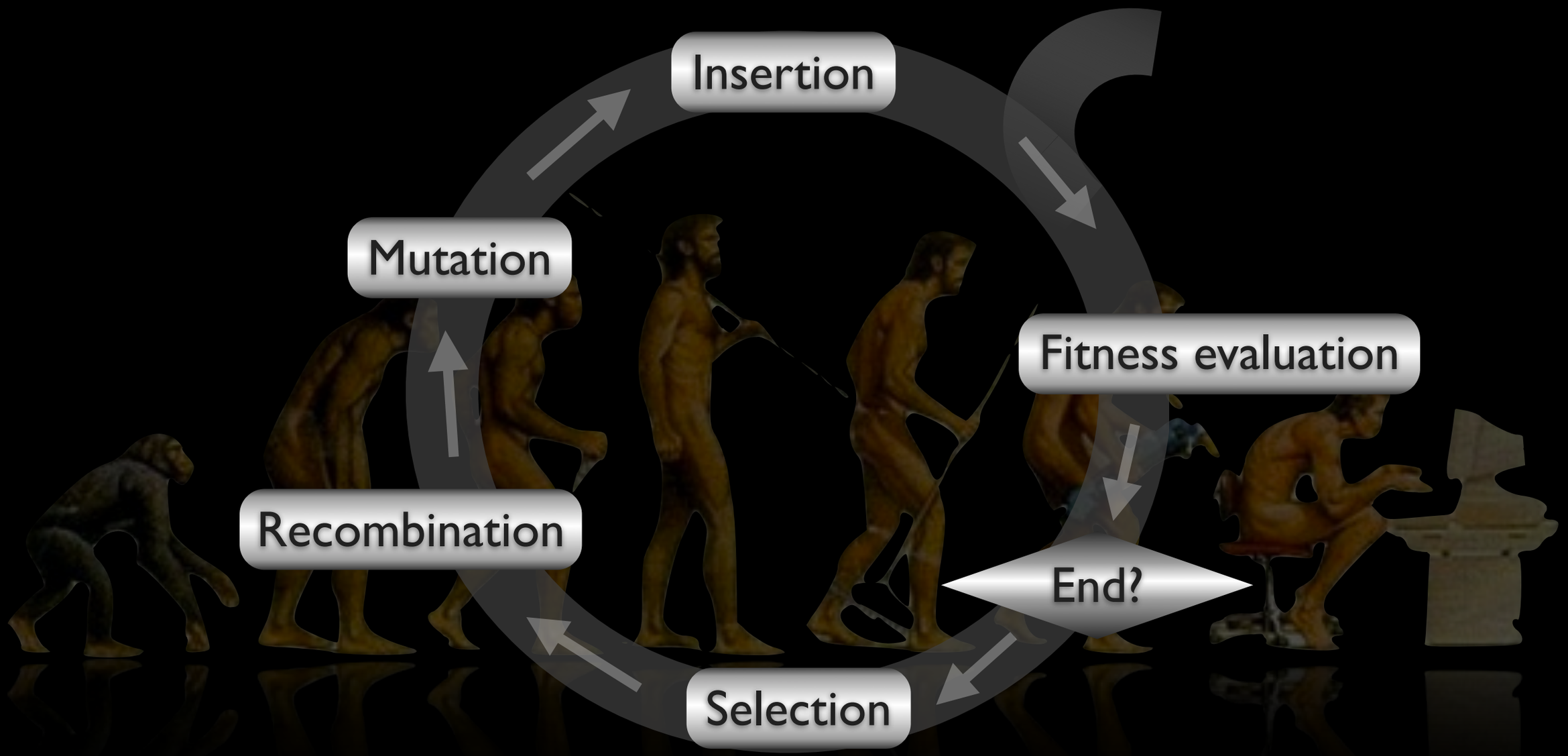
Evolutionary Testing



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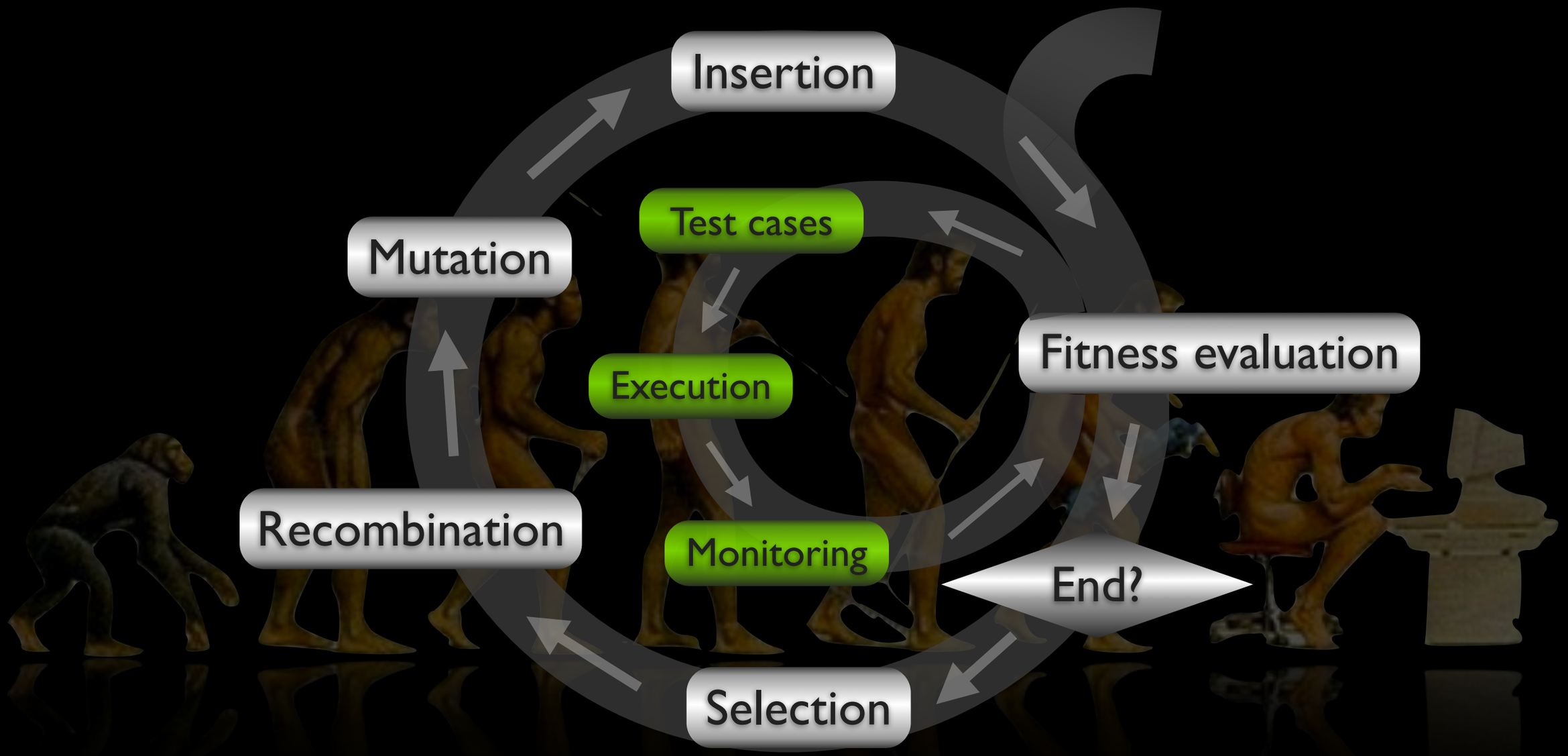

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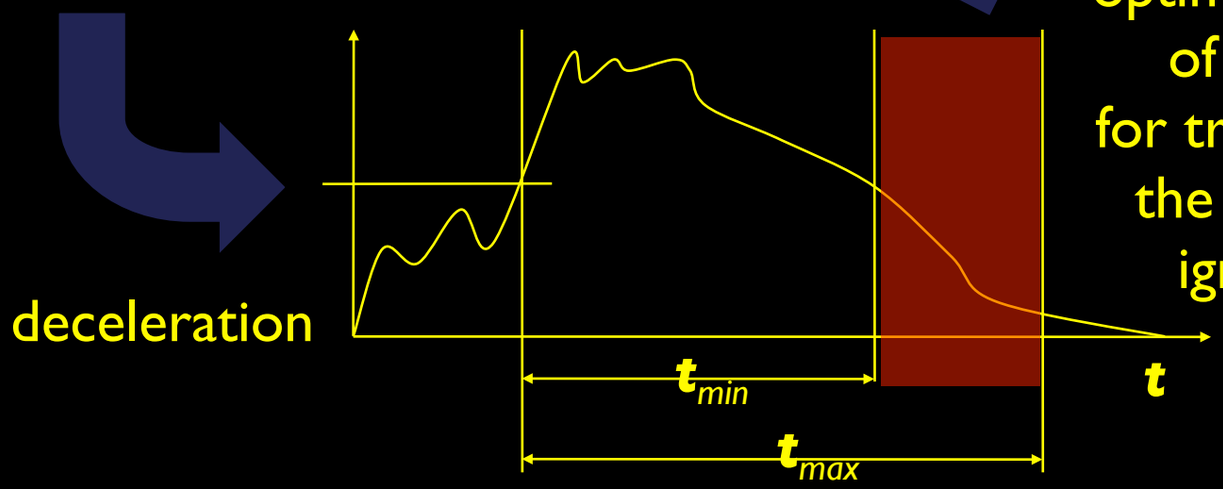
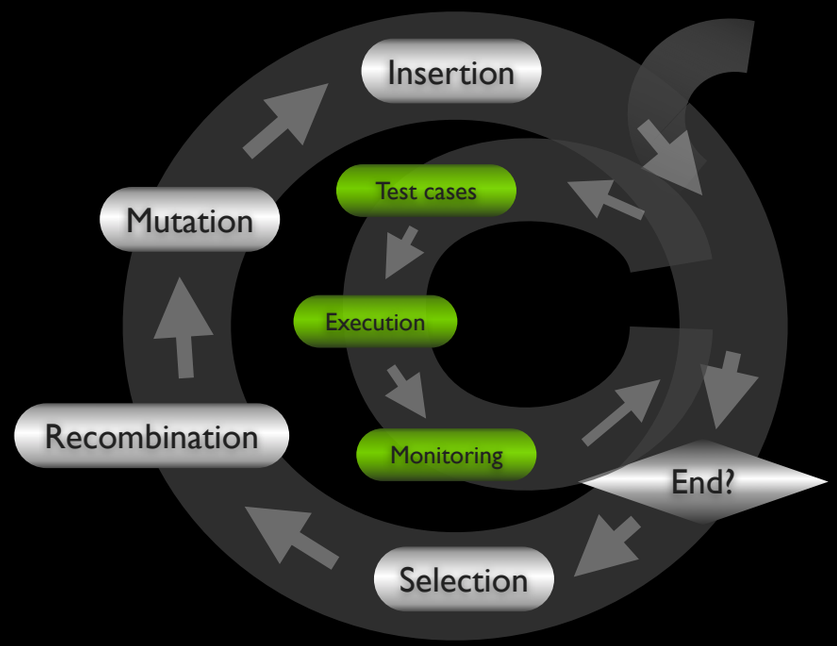
Daimler Temporal Testing

optimal point of time for triggering the airbag igniter





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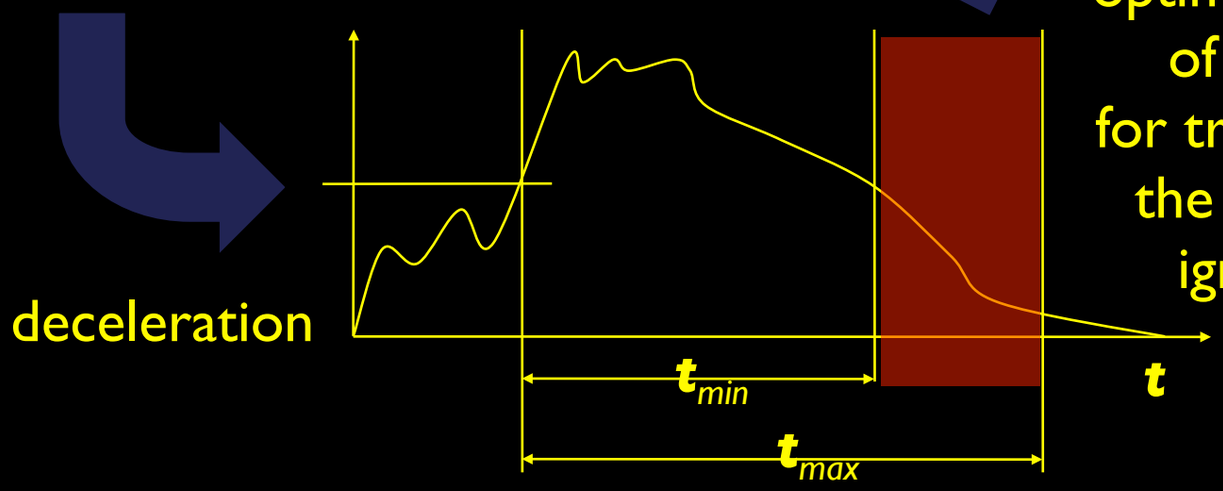

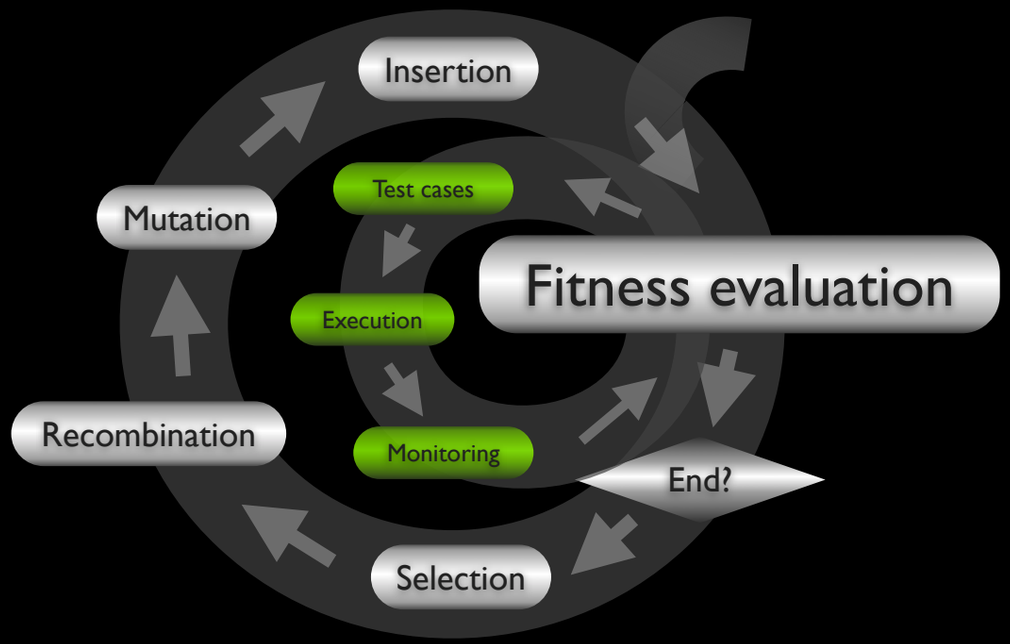

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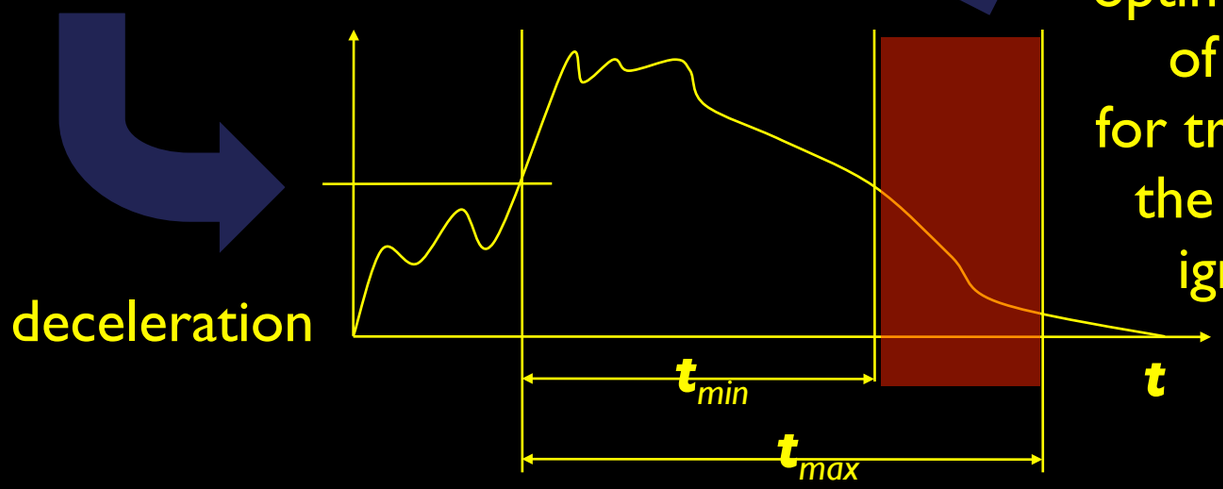

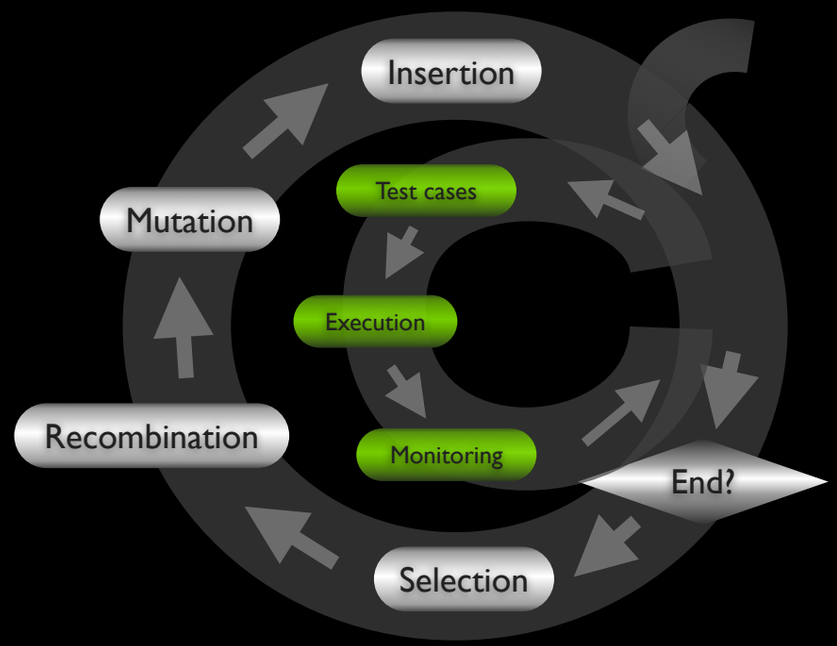

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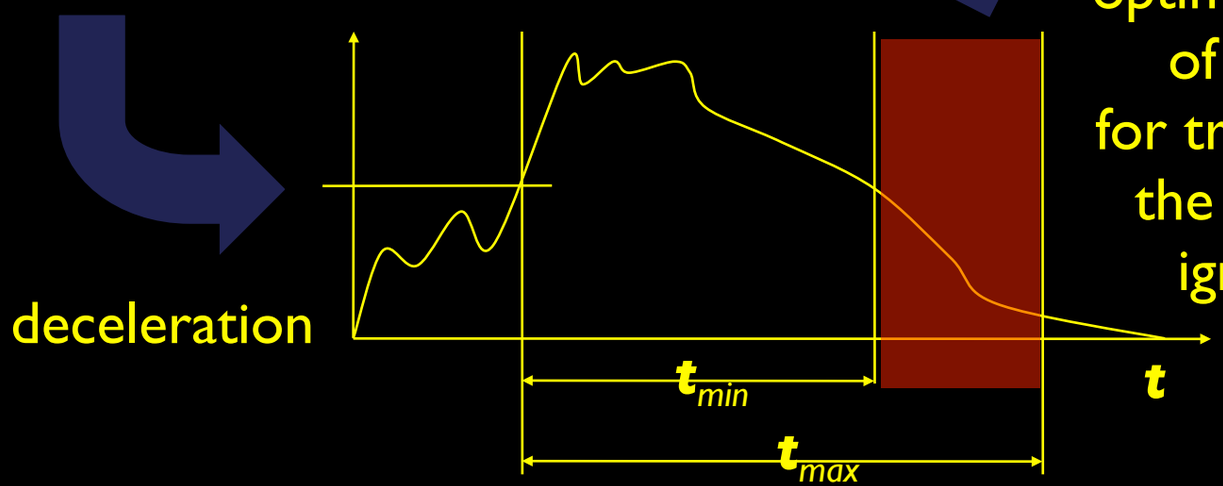

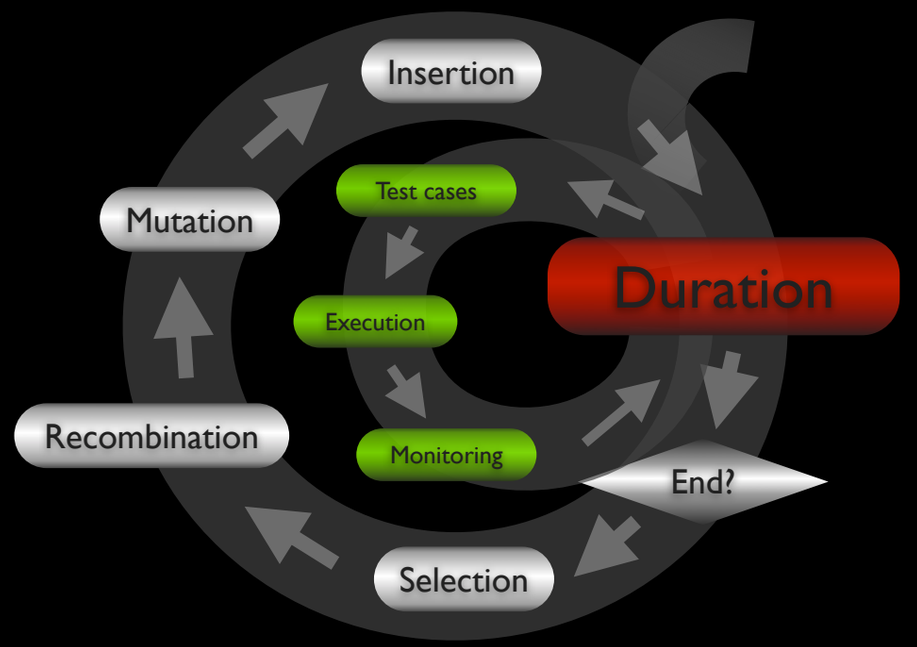

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Multi Objective Search

Many problems have multiple objectives

Often we have many metrics

Recent SBSE work has been multi objective

Pareto optimality can yield insight

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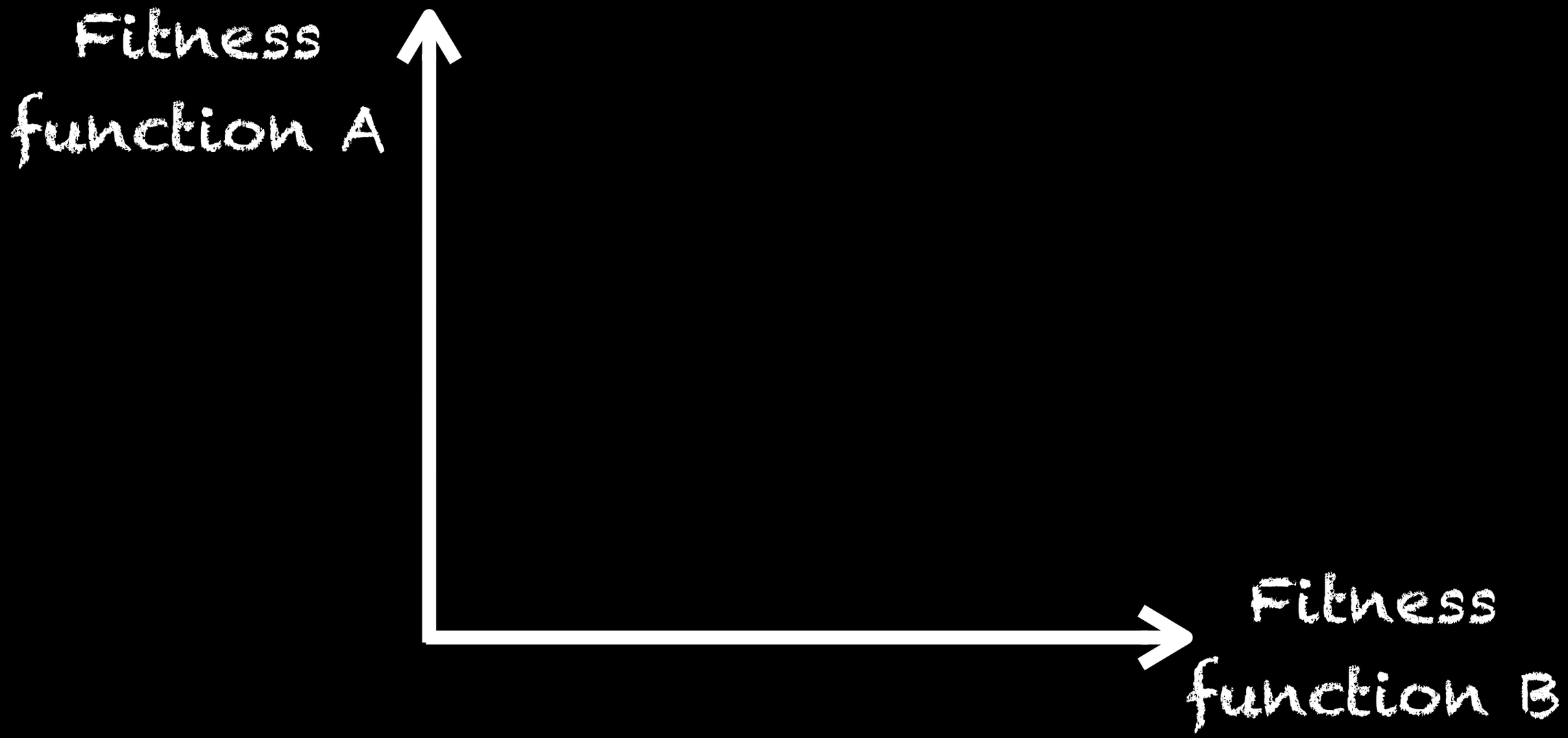

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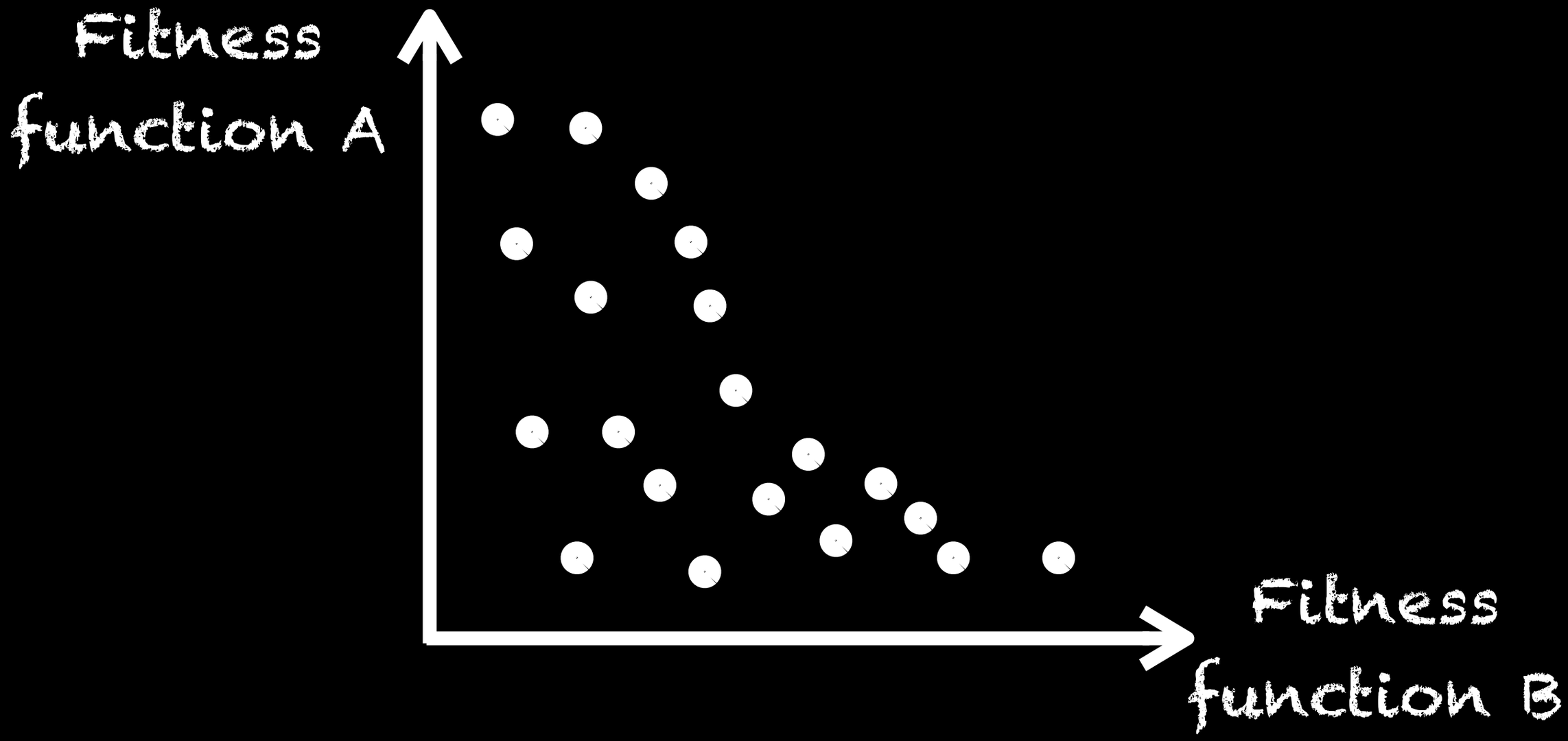

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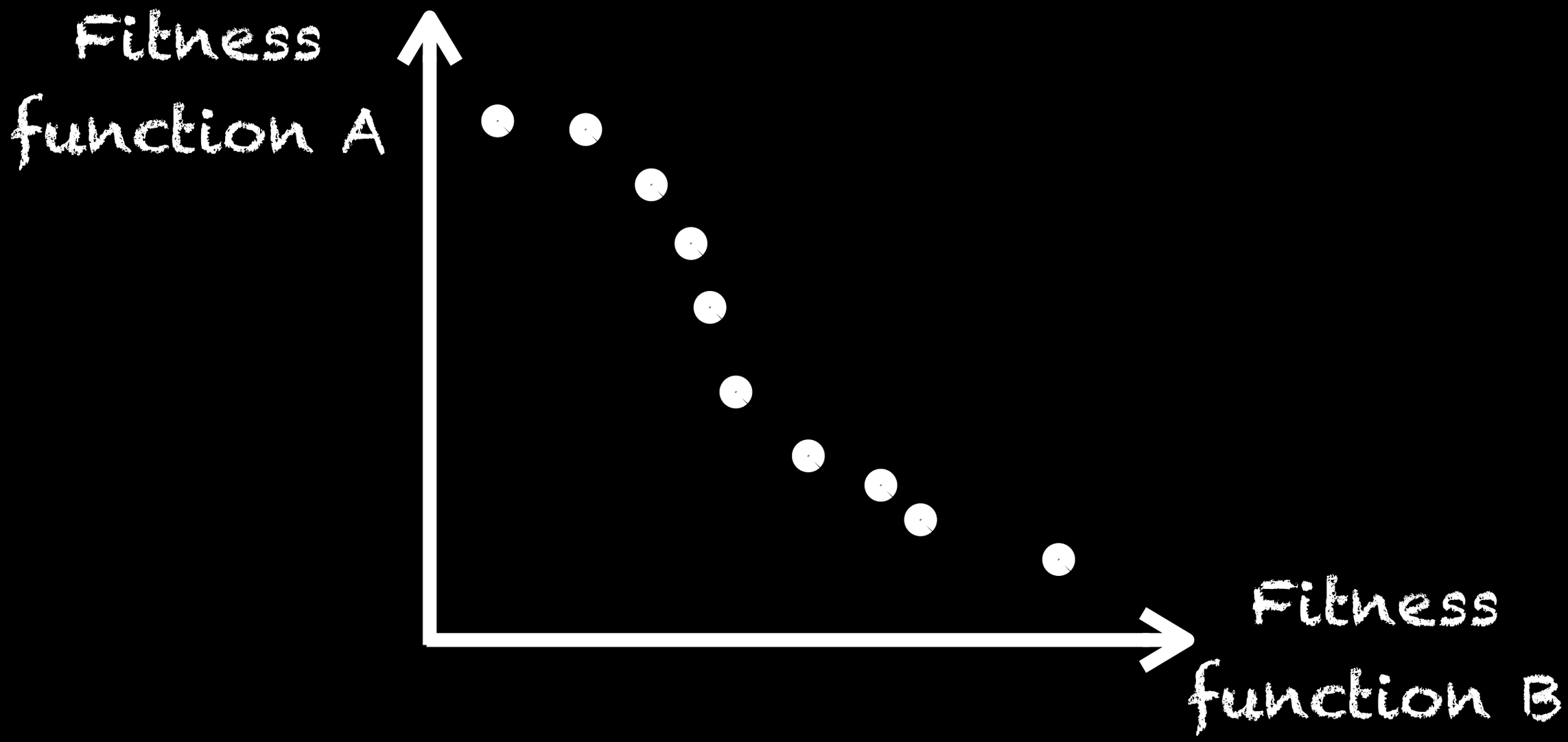

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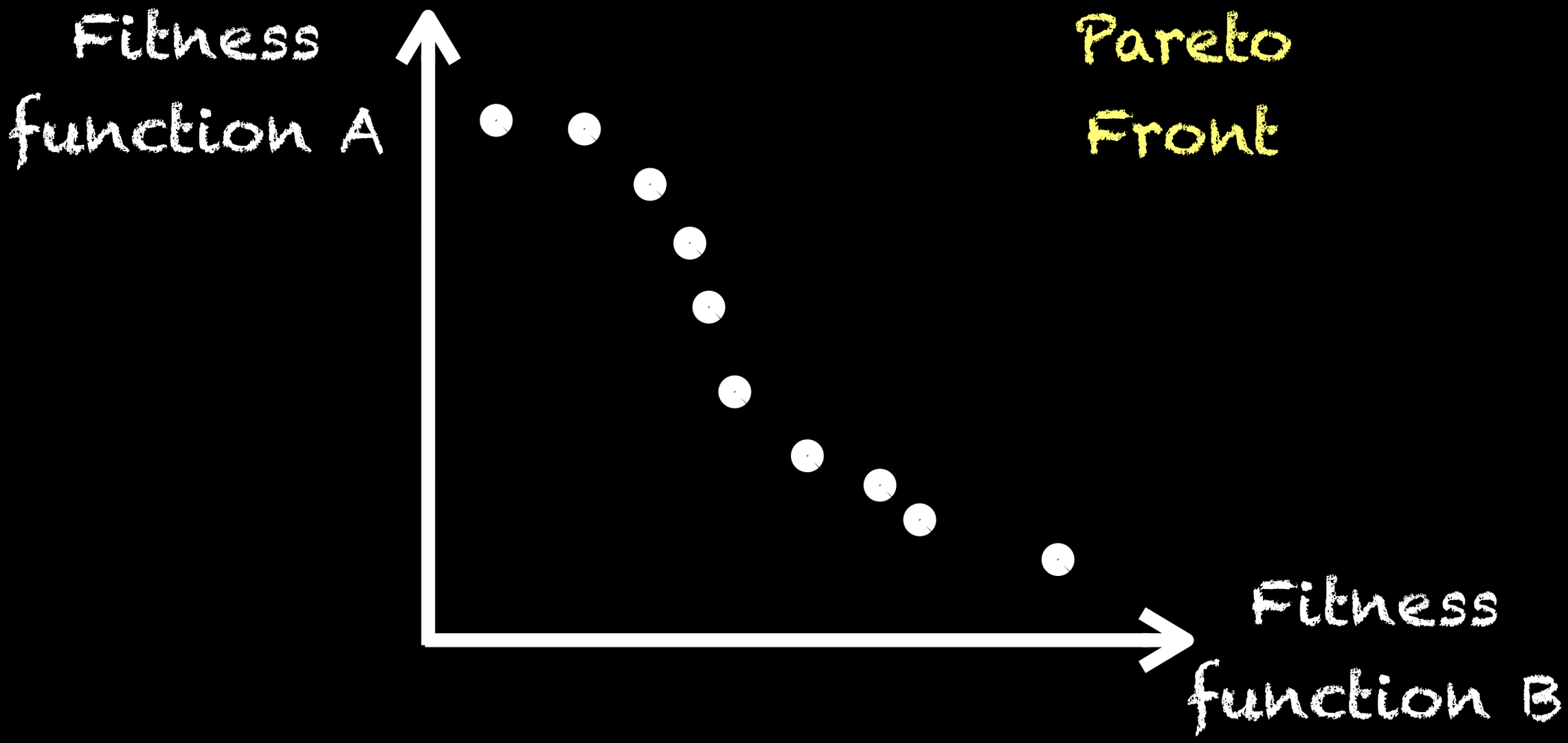

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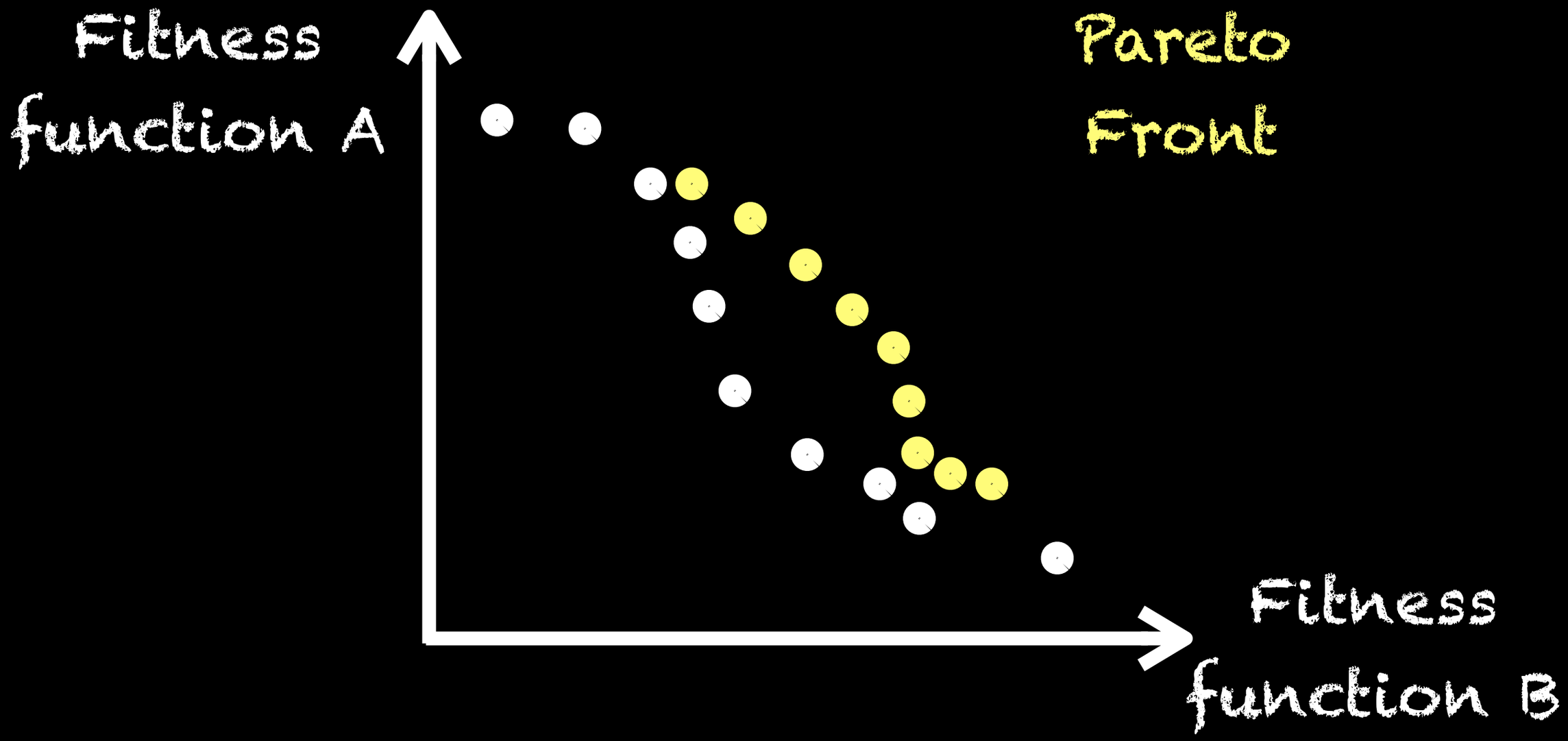

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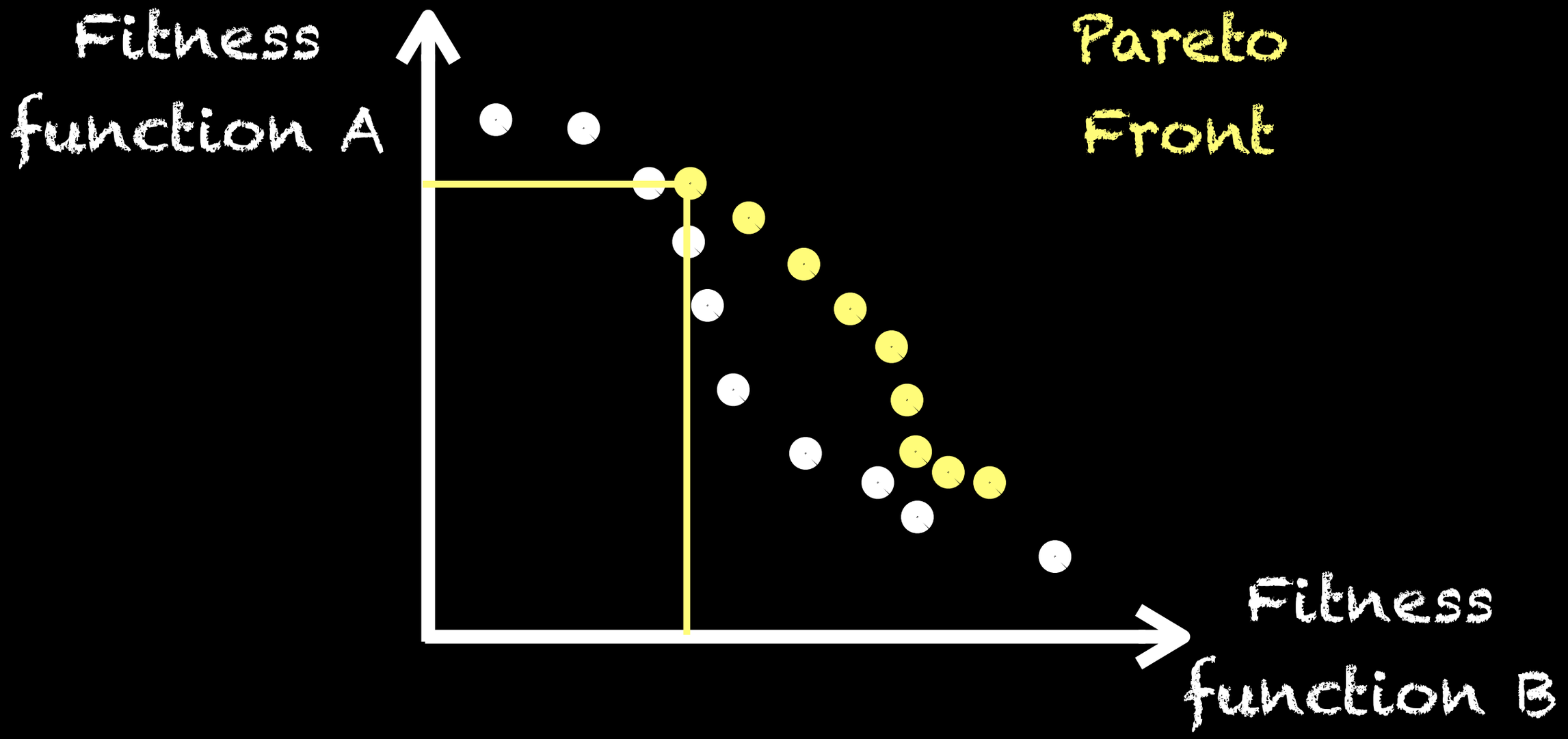

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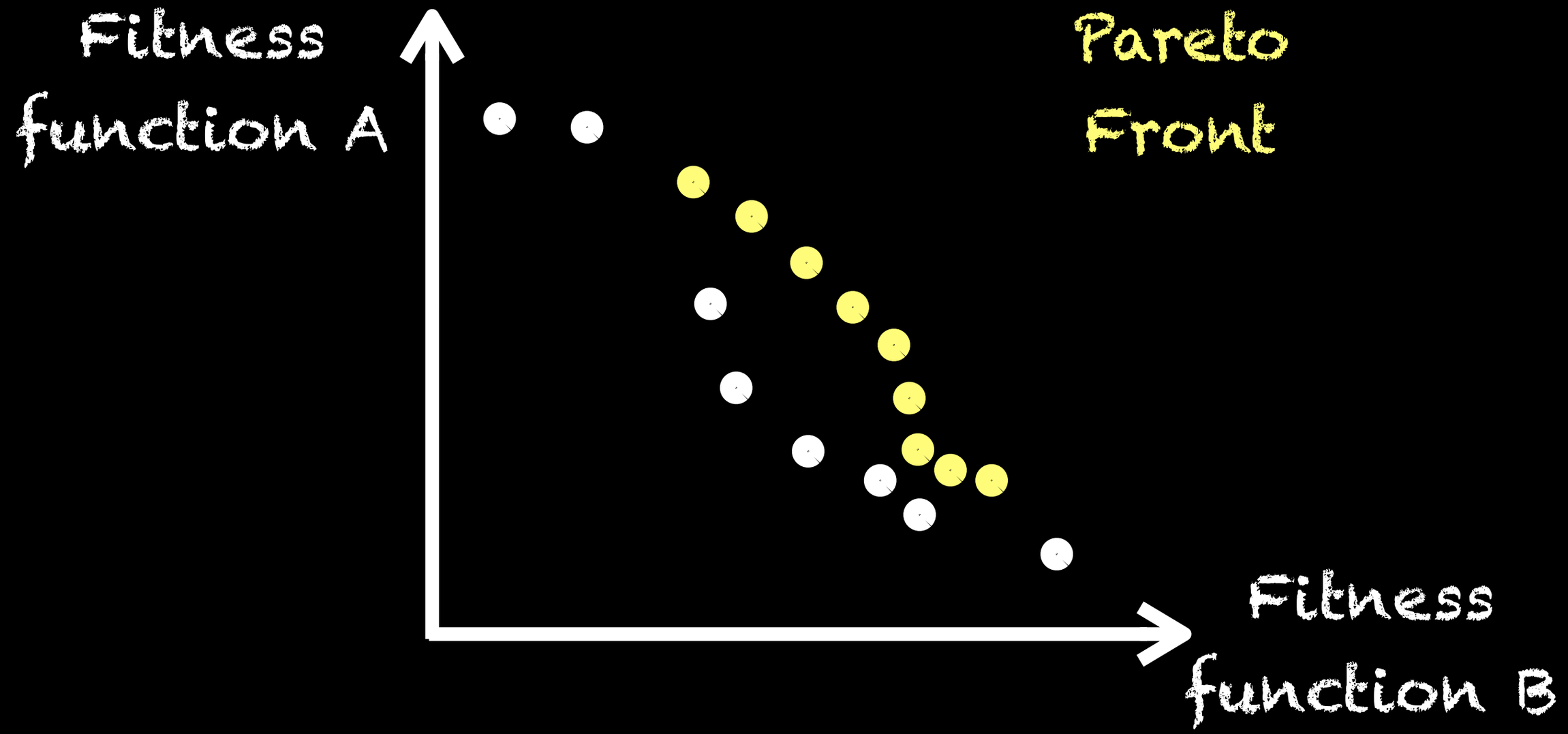

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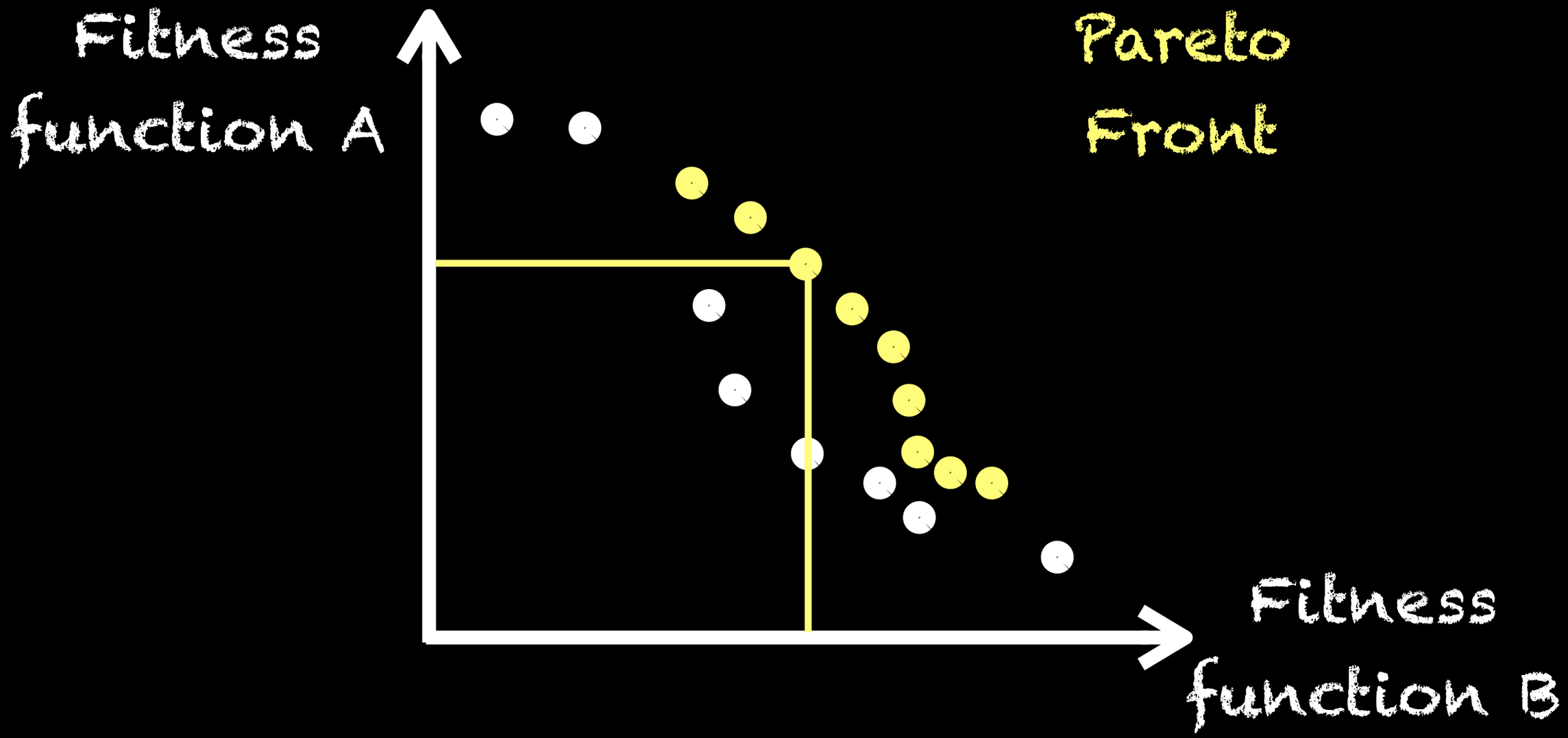

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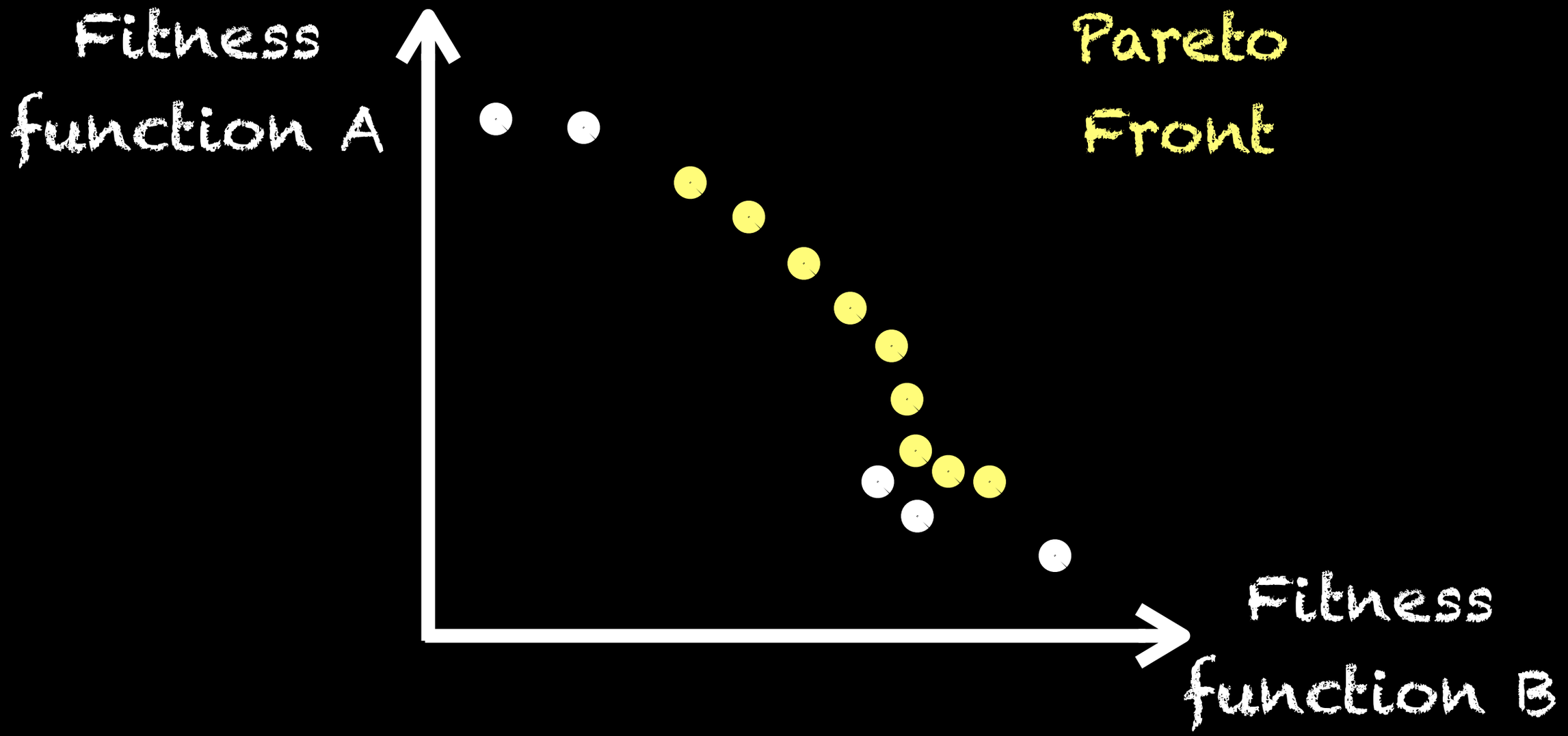
Multi Objective Search



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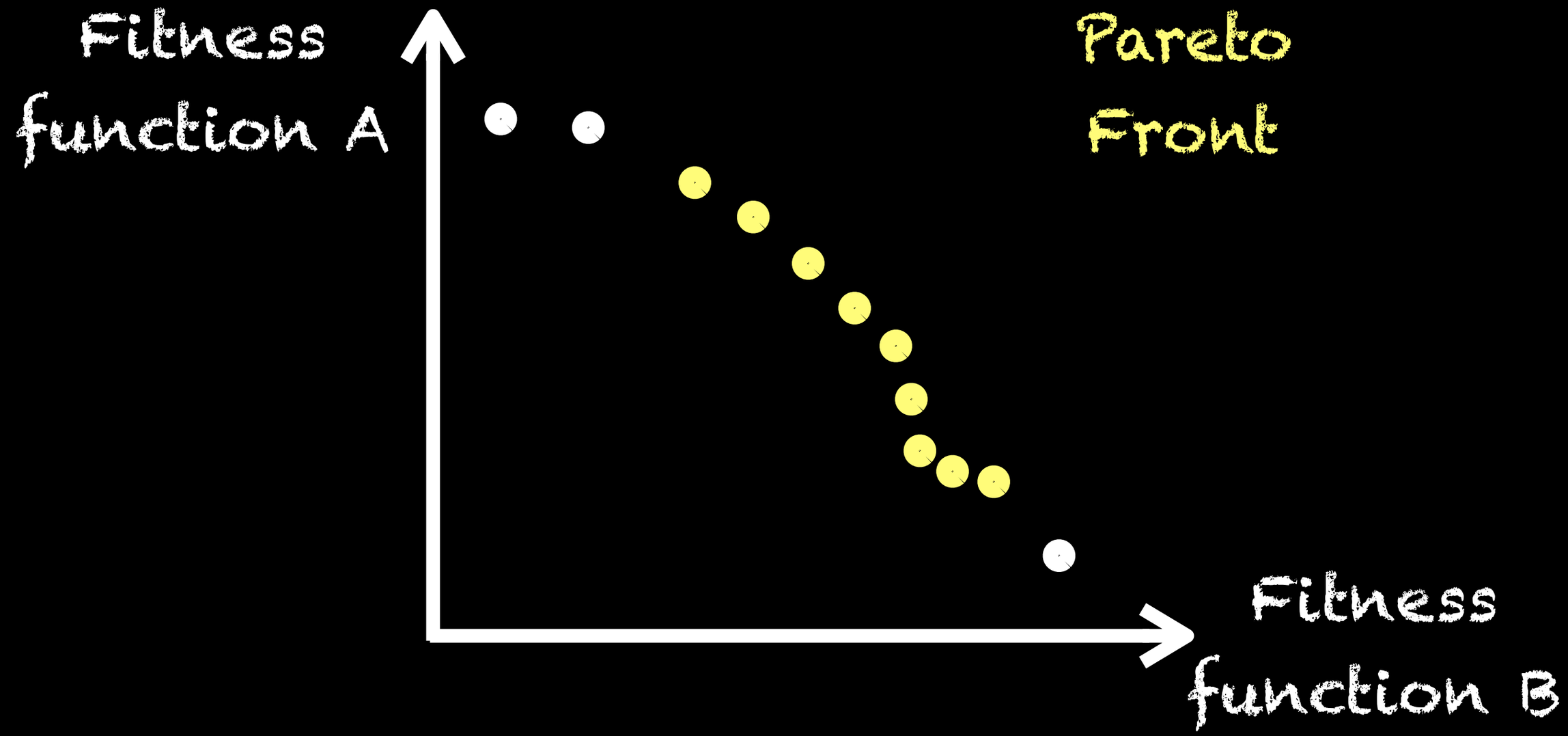

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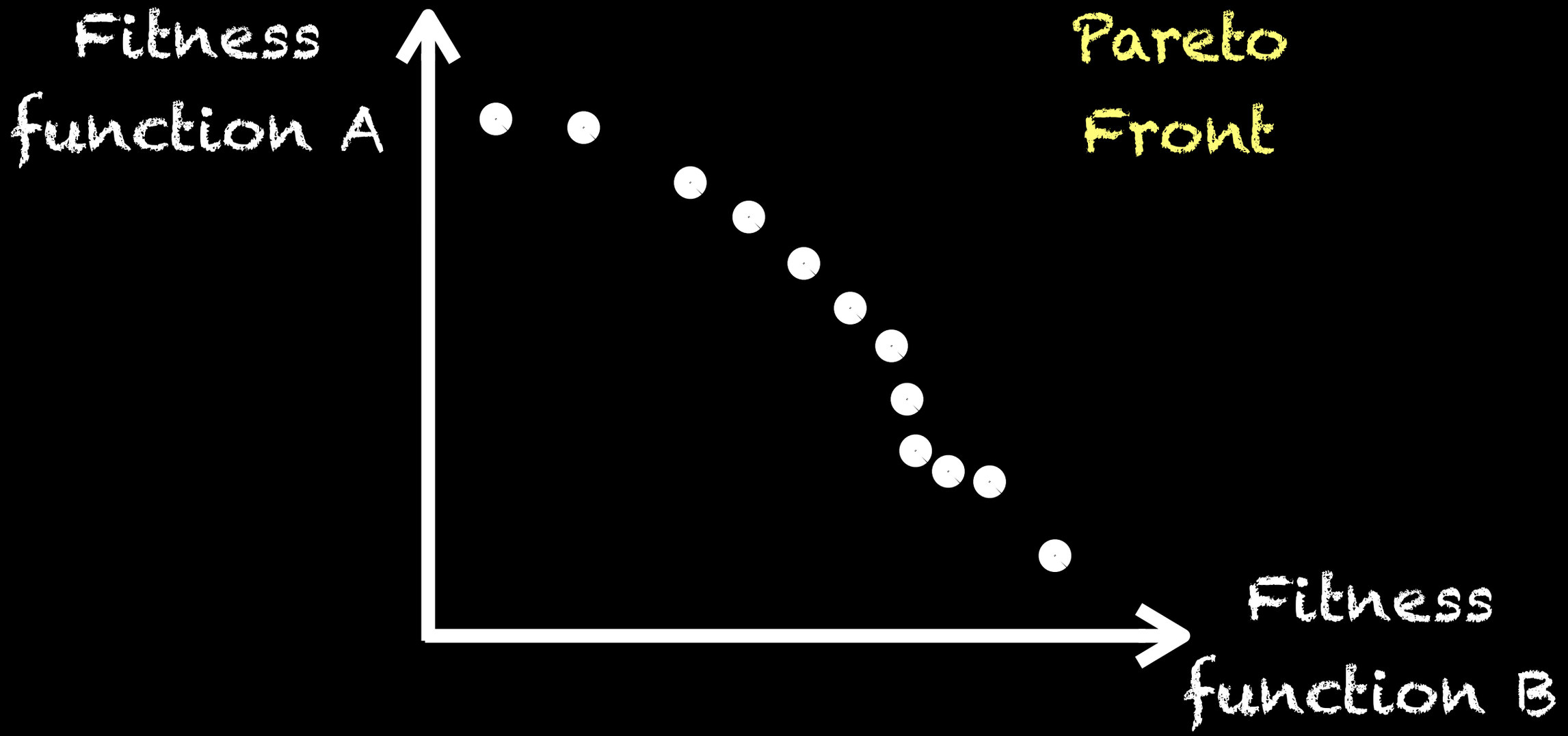

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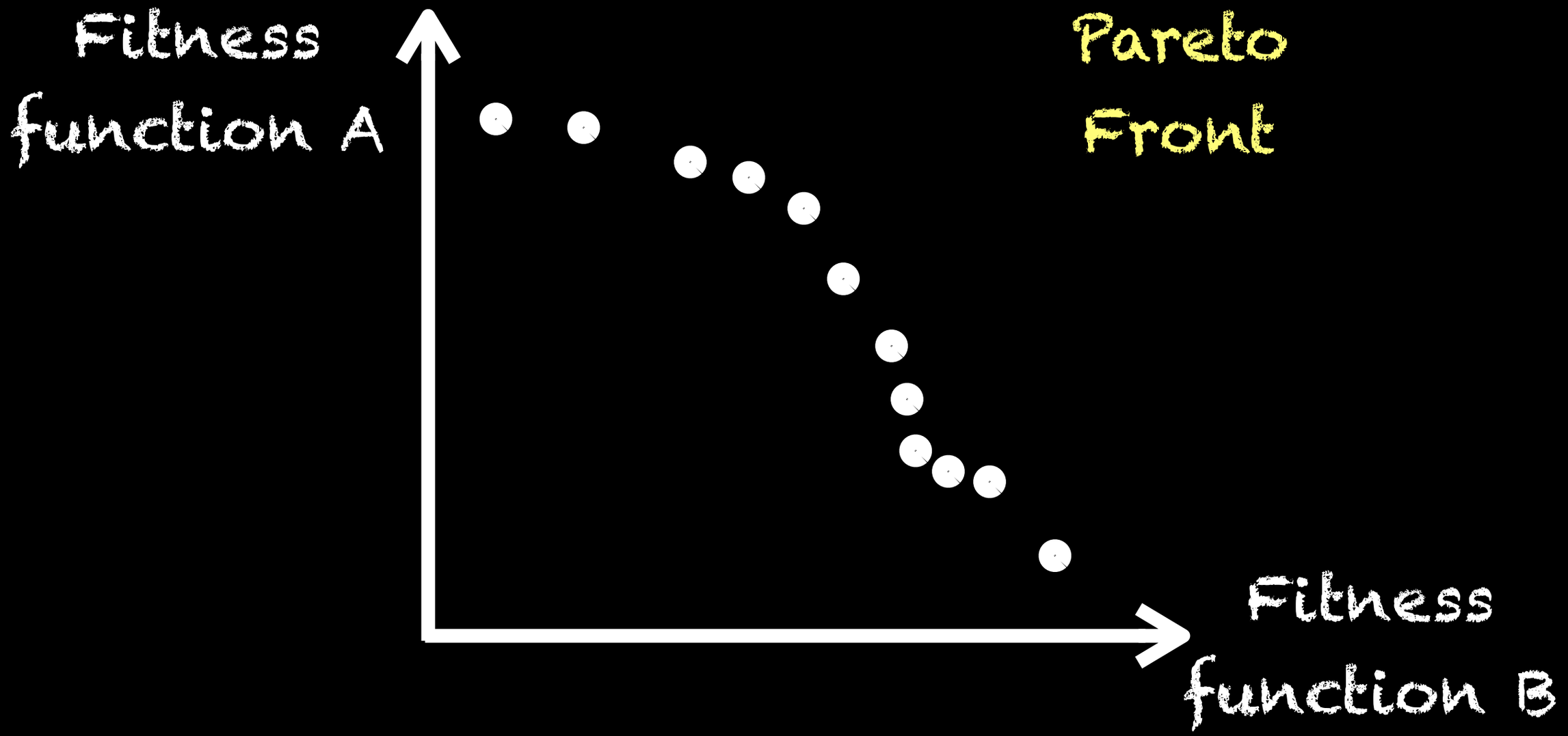

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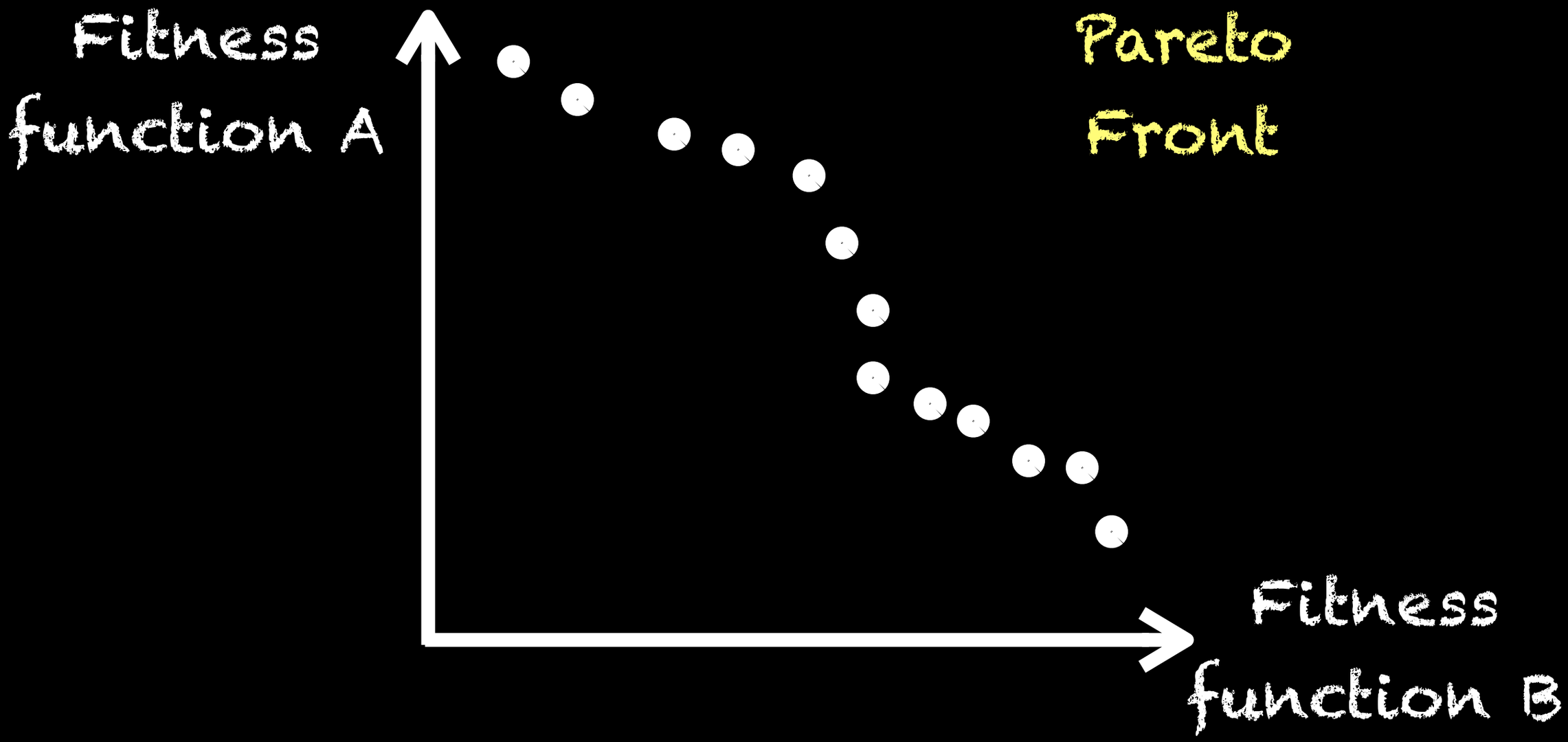

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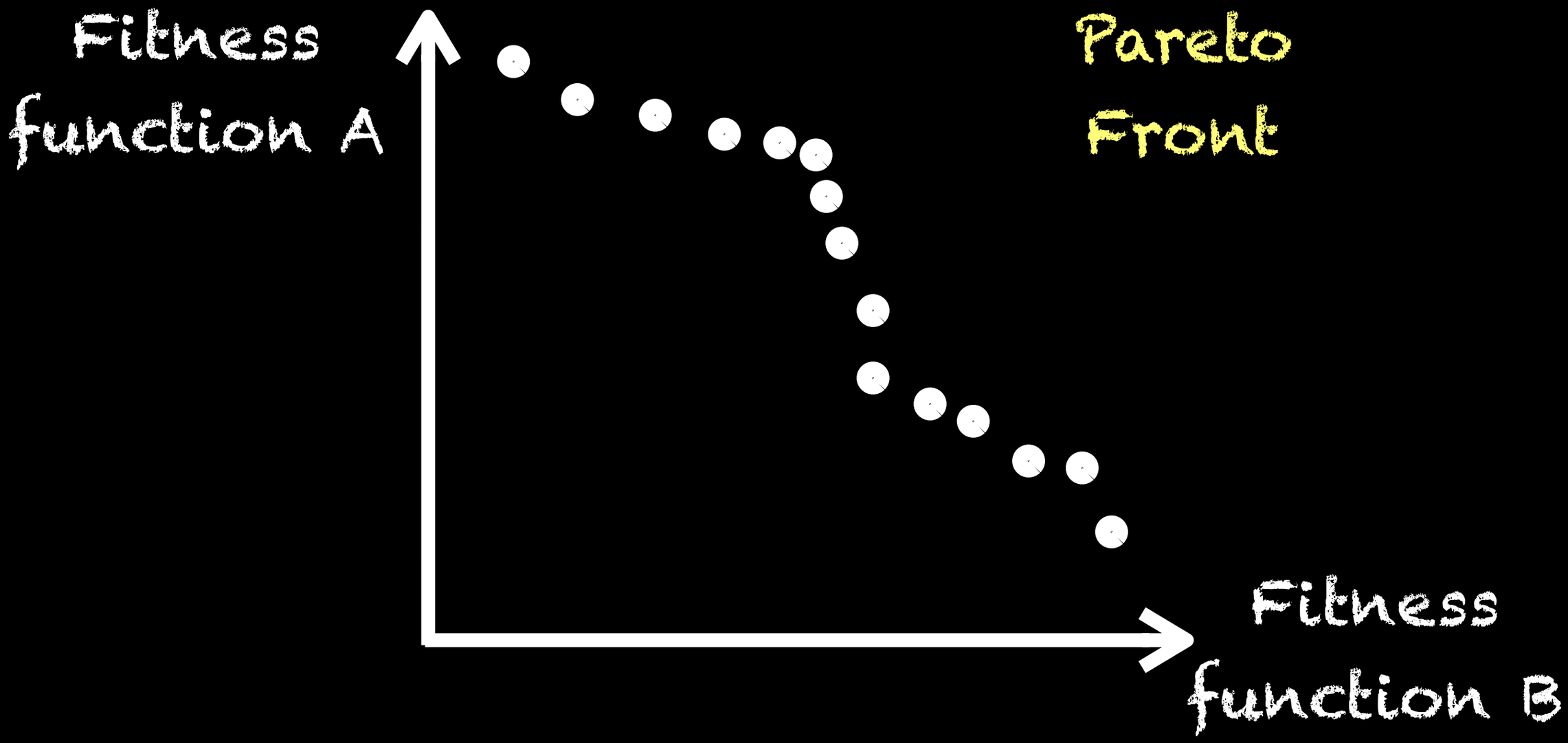

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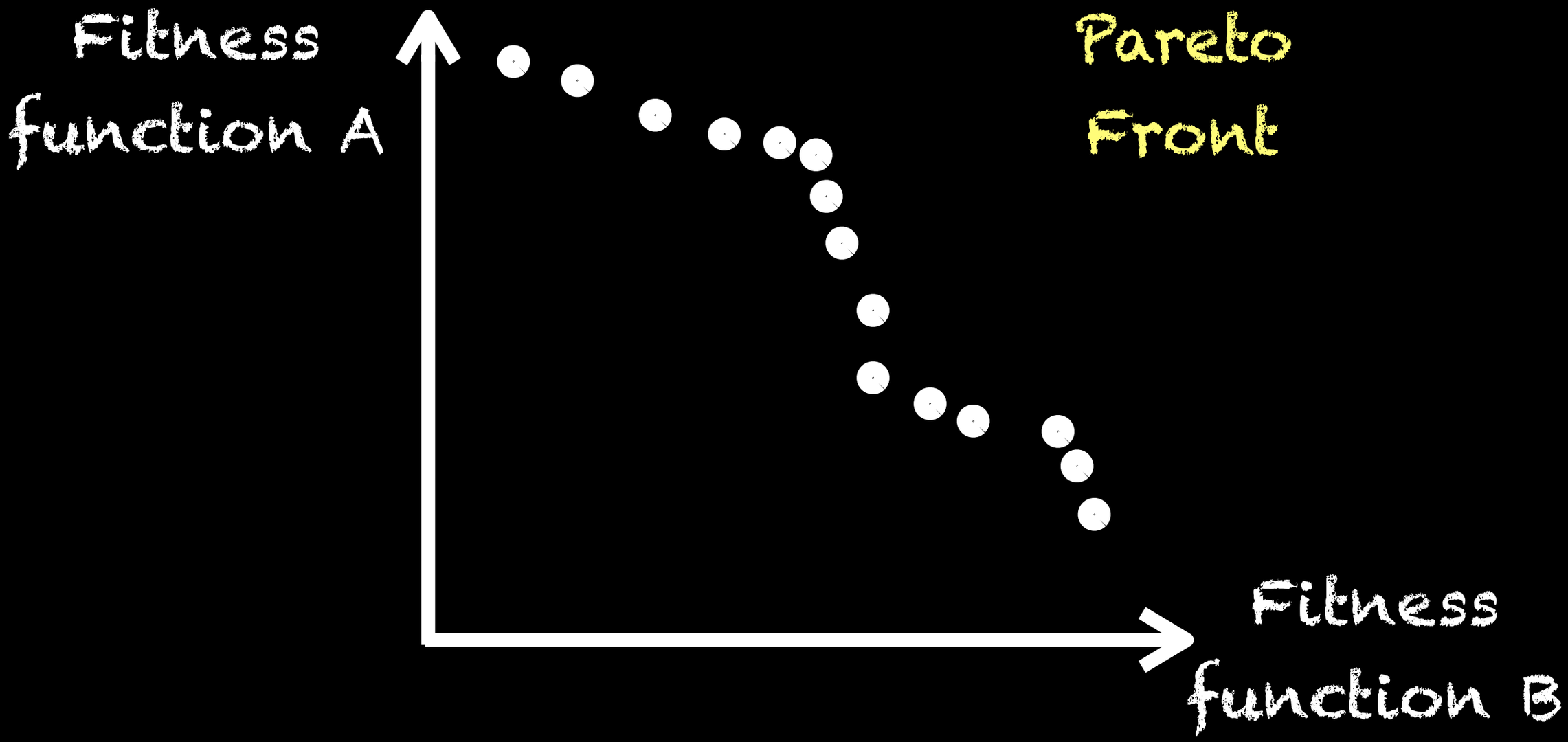

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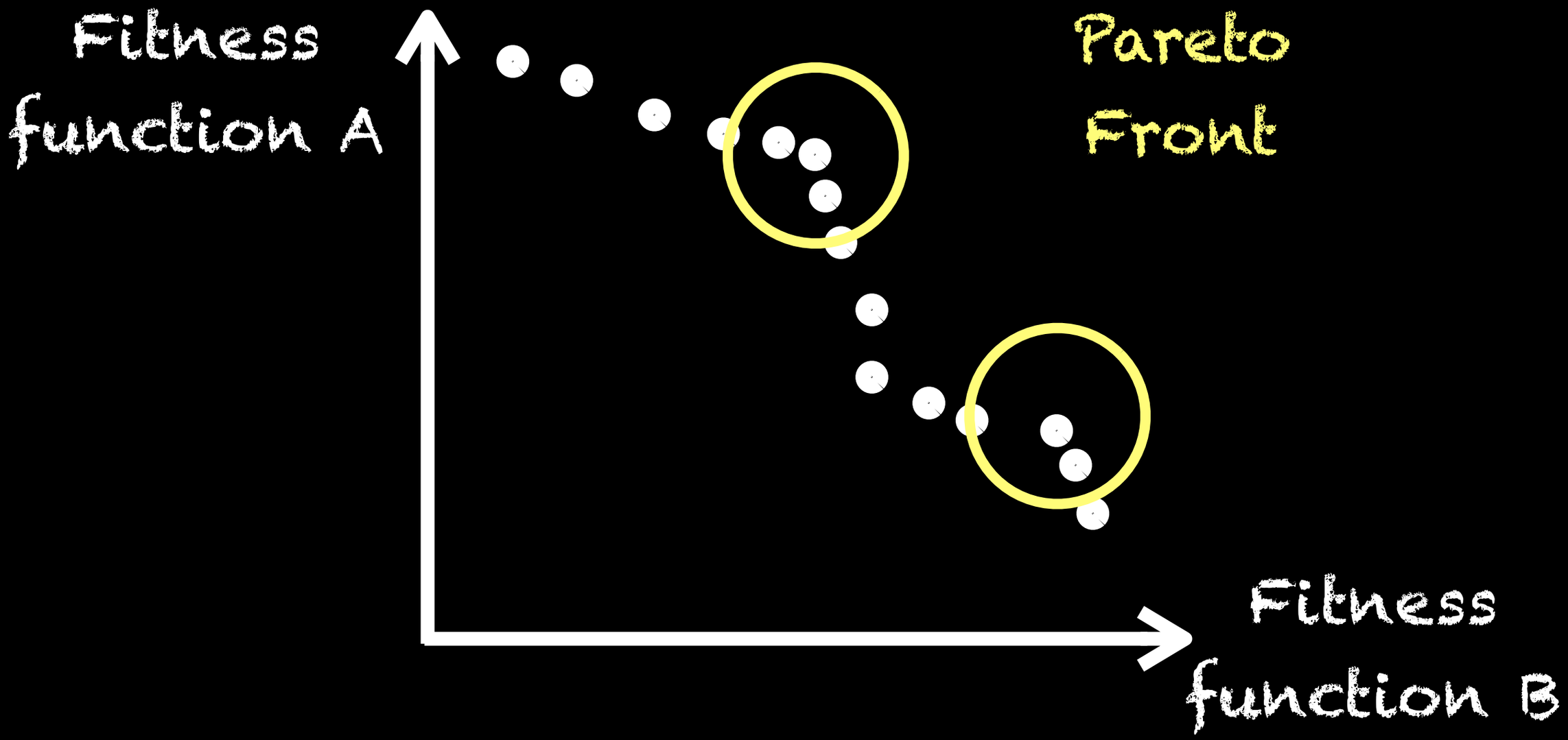

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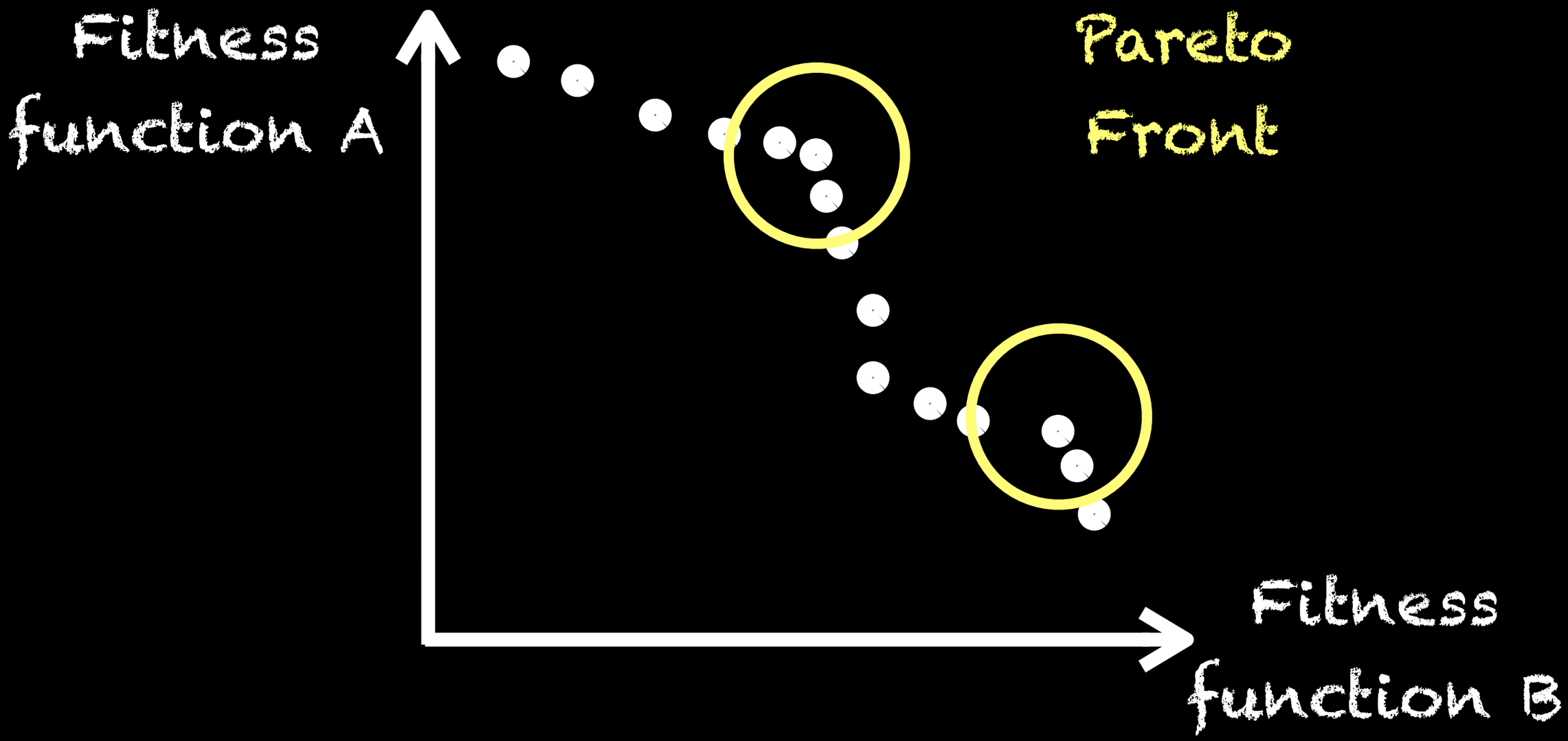
Direction of front growth



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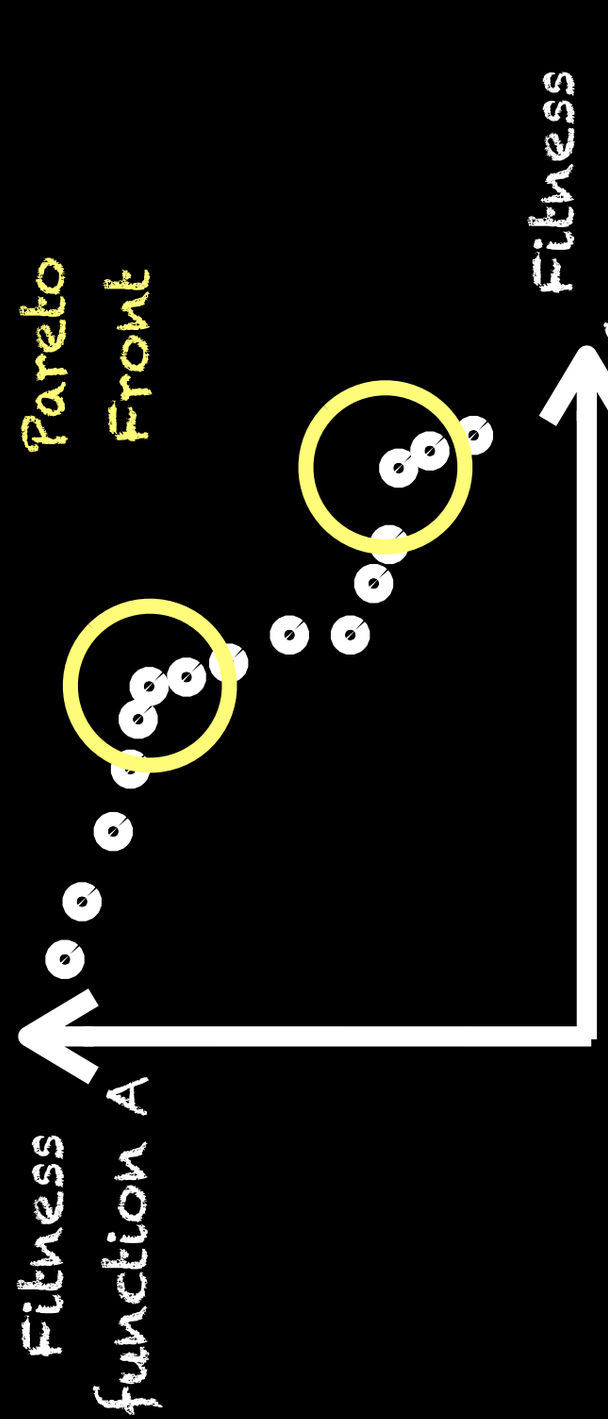

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Pareto Optimal SBSE

Regression Testing

Requirements Analysis

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Capture requirements | Generate tests | Explore designs | Maintain evolve | Regression test

Regression Testing

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Regression Test Selection

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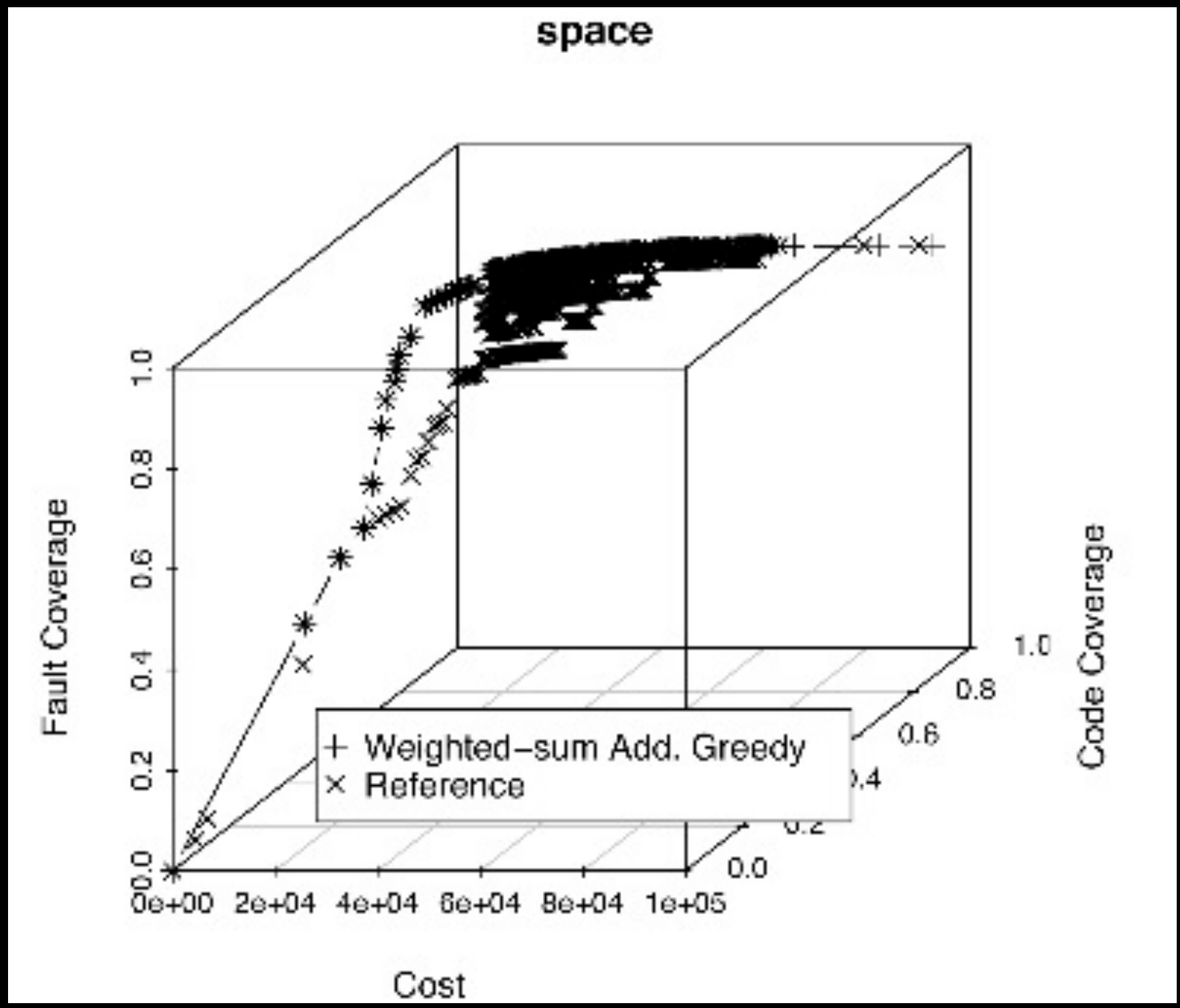
Regression Test Selection



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Customers

Requirements

Cost

Customers' value for each requirement

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The Next Release Problem

$$C = \{c_1, \ldots, c_j, \ldots, c_m\} \quad R = \{r_1, \ldots, r_i, \ldots, r_n\}$$

$$Weight = \{w_1, \ldots, w_j, \ldots, w_m\} \quad Cost = \{cost_1, \ldots, cost_n\}$$

$$value(r_i, c_j)$$

$$score_i = \sum_{j=1}^{m} w_j \times value(r_i, c_j)$$

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Motorola Cell Phone Requirements

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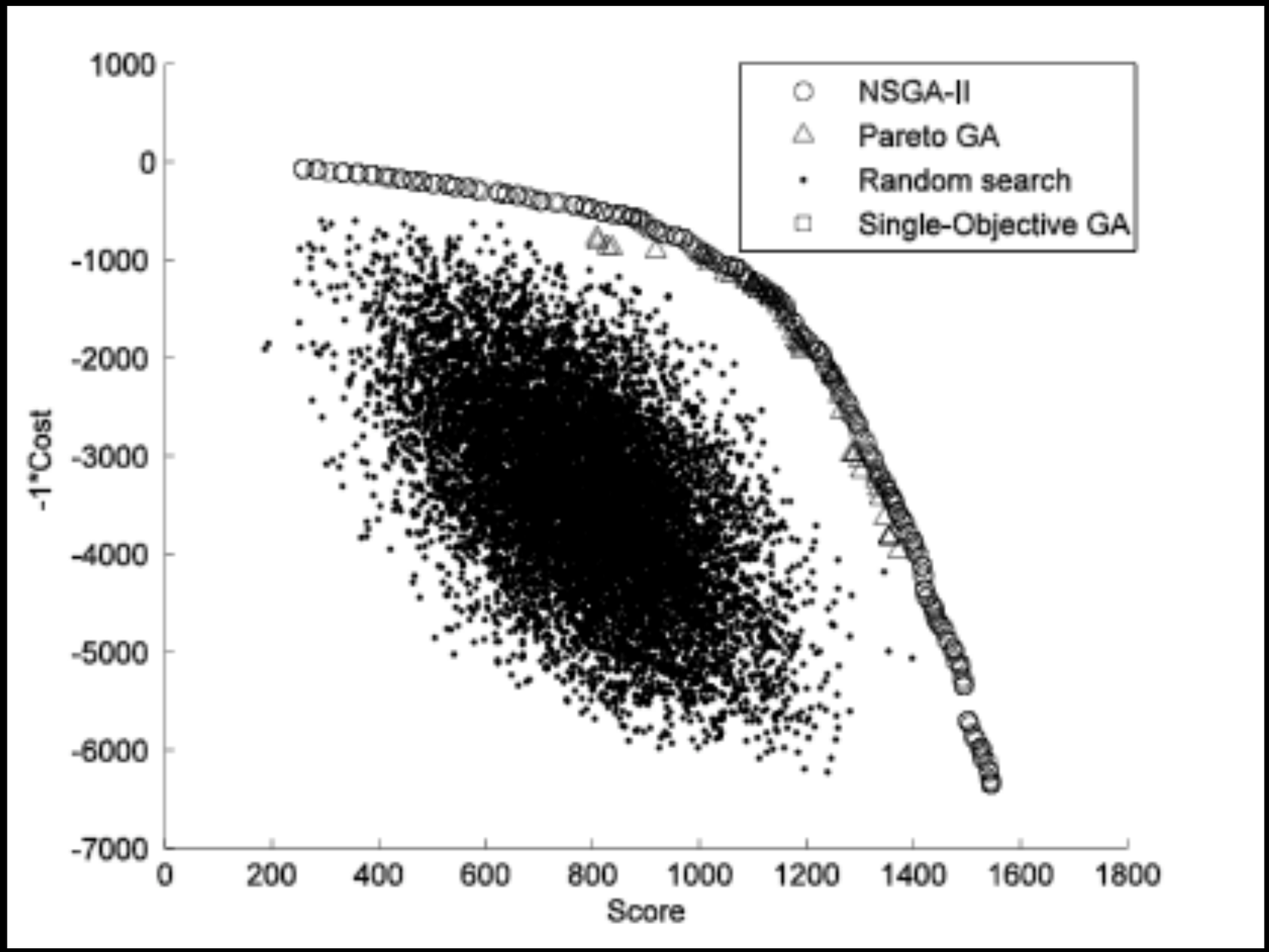
Motorola Cell Phone Requirements



SBSE is so generic

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SBSE is so generic

Test generation

- Fitness function: time ...
- Representation: input vector

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SBSE is so generic

Test generation

- Fitness function: time ...
- Representation: input vector

Requirements

- Fitness function: cost, value ...
- Representation: bitset of requirements

SBSE is so generic

Test generation

- Fitness function: time ...
- Representation: input vector

Requirements

- Fitness function: cost, value ...
- Representation: bitset of requirements

Regression

- Fitness function: coverage, time, faults
- Representation: bitset of test cases

SBSE is so generic

Test generation

Fitness function: time ...

Representation: input vector

Requirements

Fitness function: cost, value ...

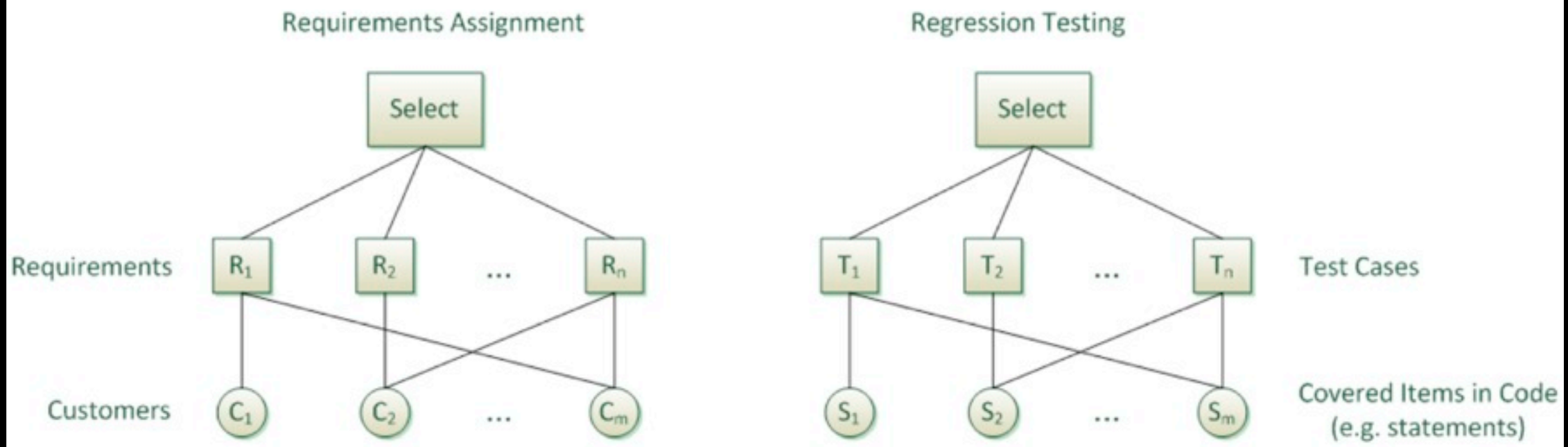
Representation: bitset of requirements

Regression

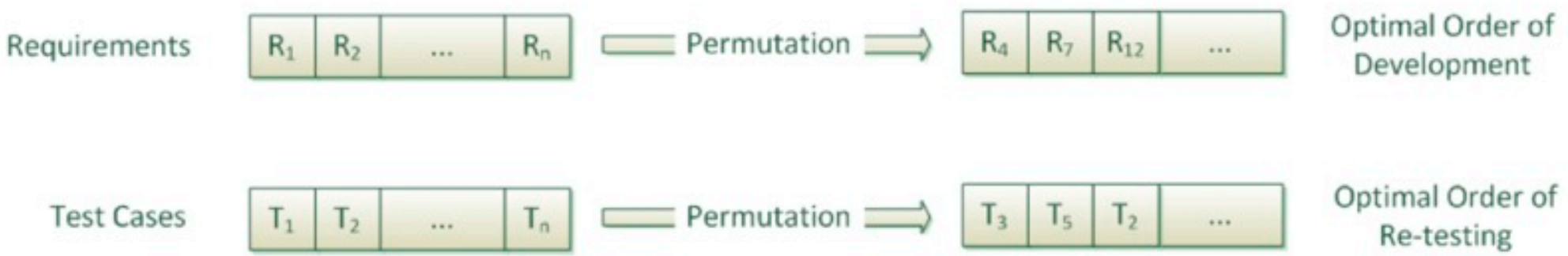
Fitness function: coverage, time, faults

Representation: bitset of test cases

Selection Problems



Prioritization Problems



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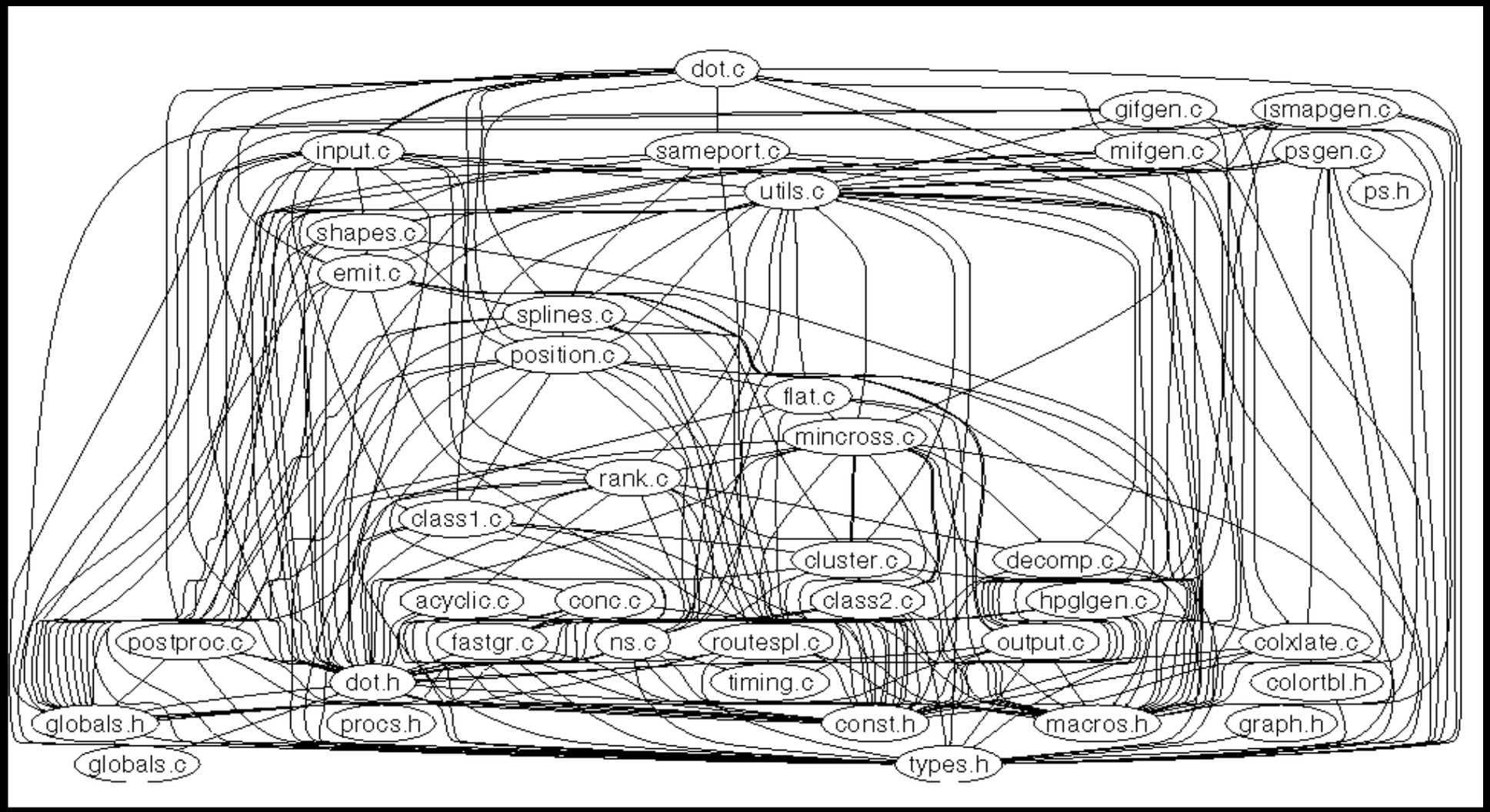
Familiar?



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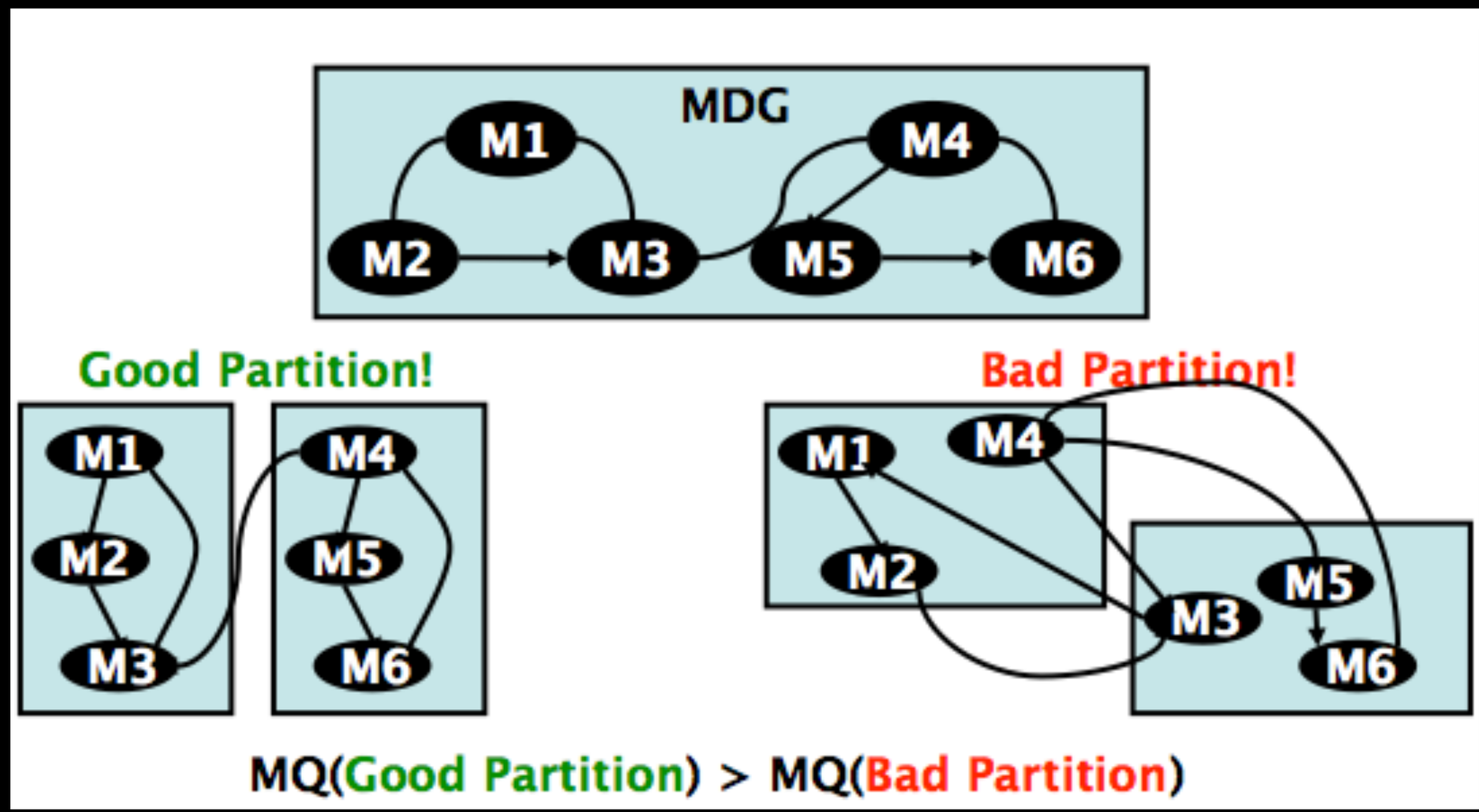
Bunch System



Some papers

1. Kata Praditwong, Mark Harman and Xin Yao: Software Module Clustering as a Multi-Objective Search Problem. TSE. To appear

2. Michael Bowman, Lionel C. Briand, Yvan Labiche: Multi-Objective Genetic Algorithm to Support Class Responsibility Assignment. ICSM, 124-133, 2007

3. Kristen R. Walcott, Mary Lou Soffa, Gregory M. Kapfhammer, Robert S. Roos: TimeAware test suite prioritization. ISSTA, 1-12, 2006

4. Shin Yoo, Mark Harman: Pareto efficient multi-objective test case selection. ISSTA, 140-150, 2007

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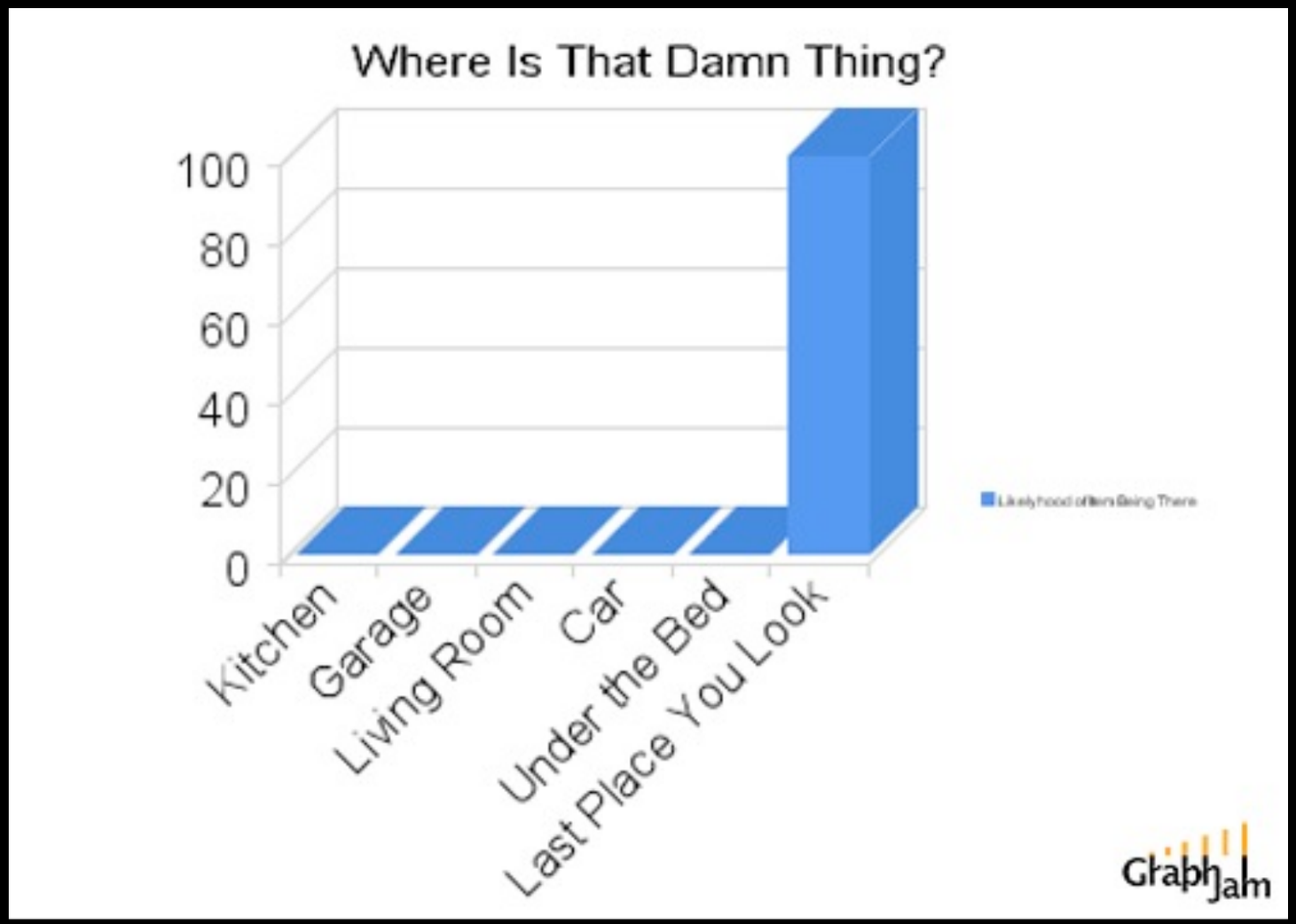

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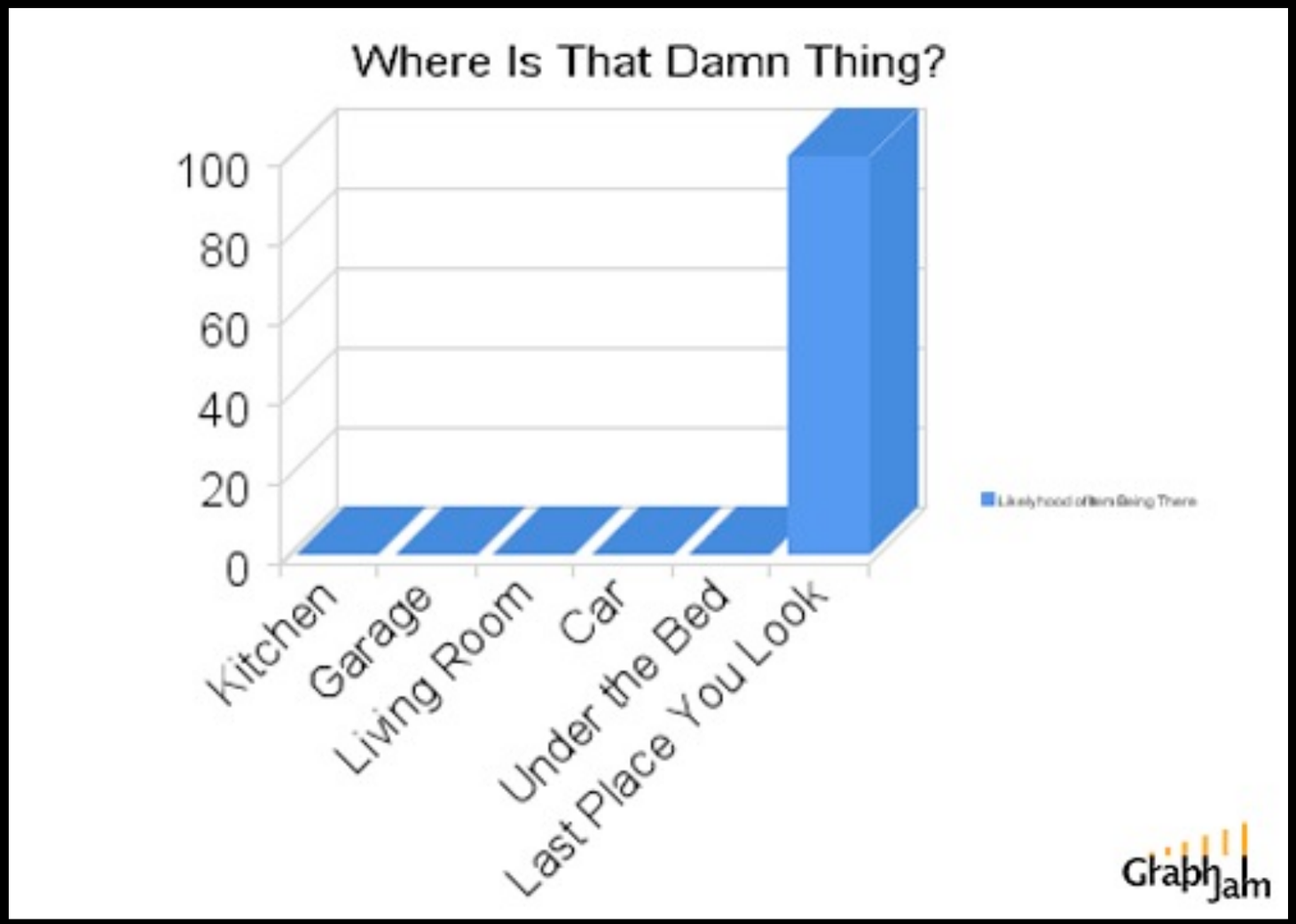
Several searchers
following different paths



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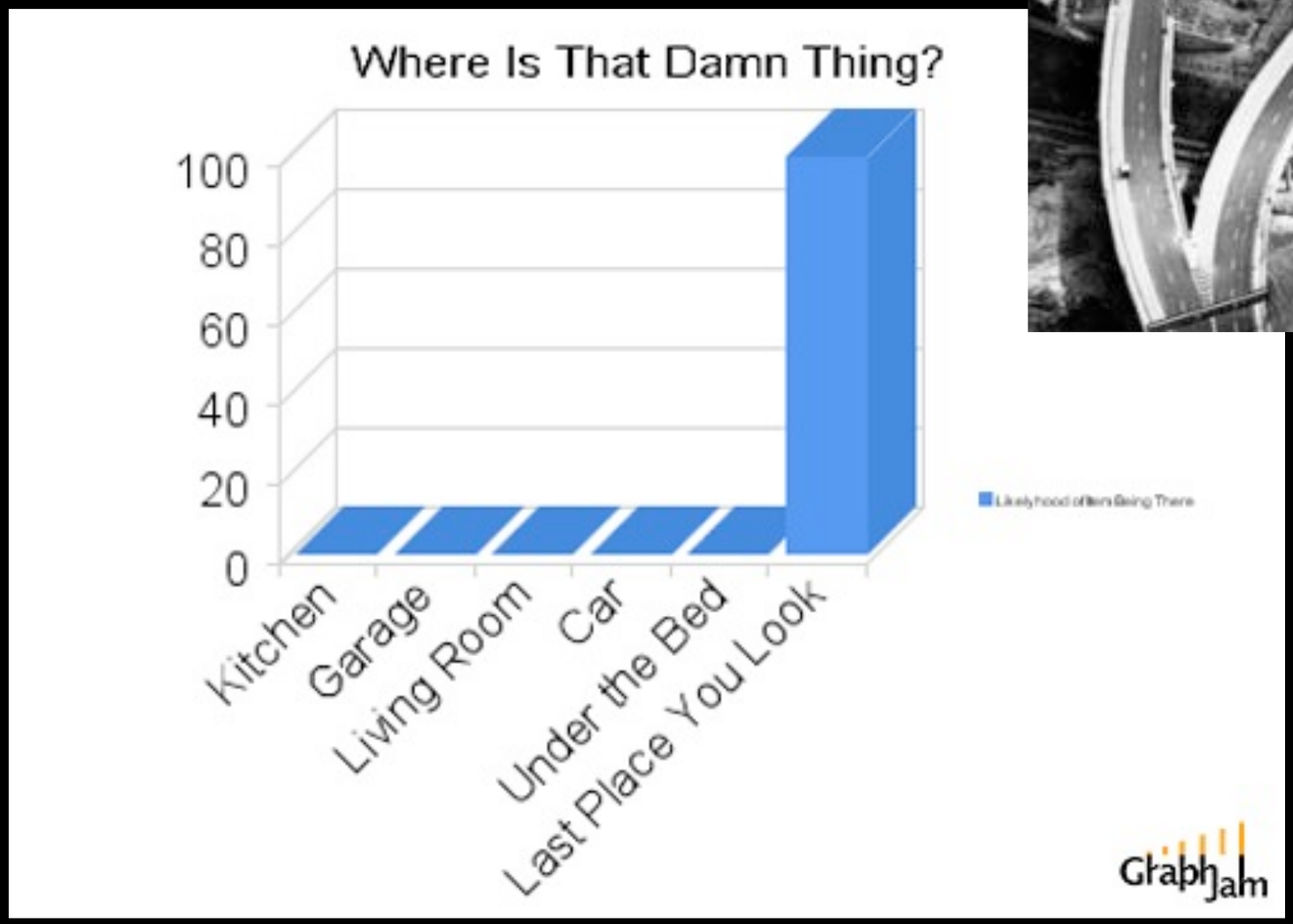

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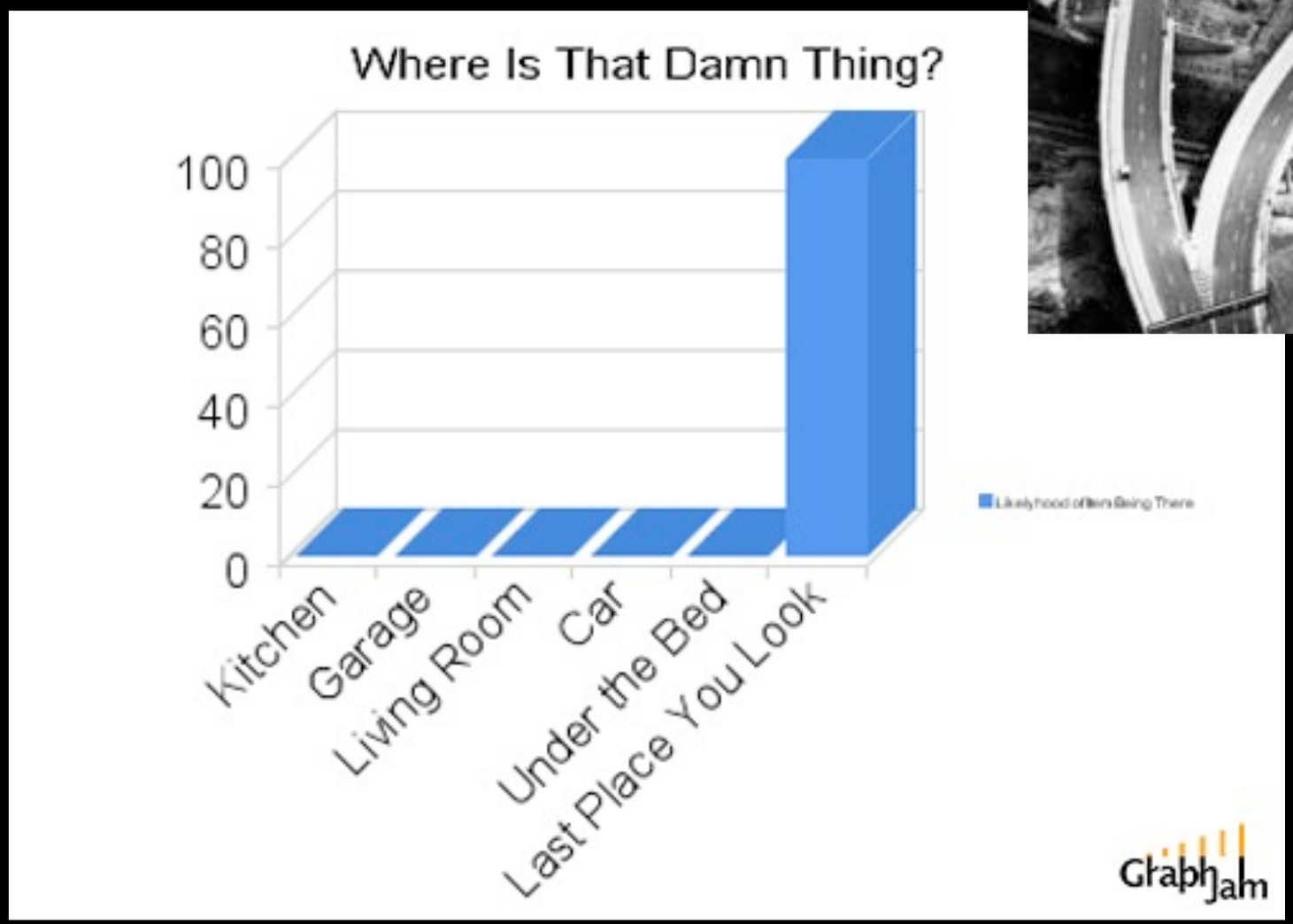

multi beats single at its own game

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Transformation	Cooper, Ryan, Schielke, Subramanian, Fatiregun, Williams
Requirements	Bagnall, Mansouri, Zhang
Effort prediction	Aguilar-Ruiz, Burgess, Dolado, Lefley, Shepperd
Management	Alba, Antoniol, Chicano, Di Pentam Greer, Ruhe
Heap allocation	Cohen, Kooi, Srisa-an
Regression test	Li, Yoo, Elbaum, Rothermel, Walcott, Soffa, Kampfhamer
SOA	Canfora, Di Penta, Esposito, Villani
Refactoring	Antoniol, Briand, Cinneide, O'Keeffe, Merlo, Seng, Tratt
Test Generation	Alba, Binkley, Bottaci, Briand, Chicano, Clark, Cohen, Gutjahr, Harrold, Holcombe, Jones, Korel, Pargass, Reformat, Roper, McMinn, Michael, Sthamer, Tracy, Tonella, Xanthakis, Xiao, Wegener, Wilkins
Modularization	Antoniol, Lutz, Di Penta, Madhavi, Mancoridis, Mitchell, Swift
Model checking	Alba, Chicano, Godefroid
Probe dist'ion	Cohen, Elbaum
UIOs	Derderian, Guo, Hierons
Comprehension	Gold, Li, Mahdavi
Protocols	Alba, Clark, Jacob, Troya
Component sel	Baker, Skaliotis, Steinhofel, Yoo
Agent Oriented	Haas, Peysakhov, Sinclair, Shami, Mancoridis

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Why Search Based Software Engineering

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Why Search Based Software Engineering

La trahison des images 1929
René Margritte, 1898–1967

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"The famous pipe. How people reproached me for it!
And yet, could you stuff my pipe?
No, it's just a representation, is it not?
So if I had written on my picture 'This is a pipe,'
I'd have been lying!"

Quoted in: Harry Torczyner. *Magritte: Ideas and Images*. Alcuin Books.

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Traditional Engineering Artifact

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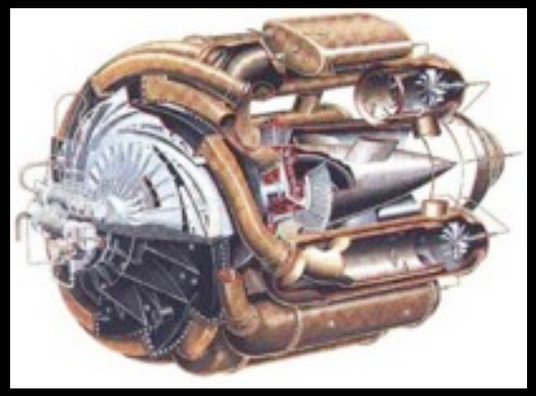
Traditional Engineering Artifact



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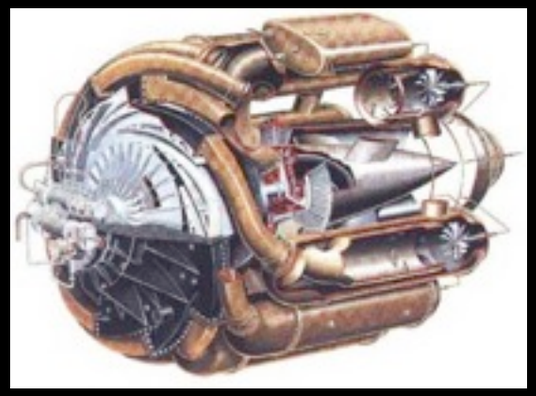

Optimization goal

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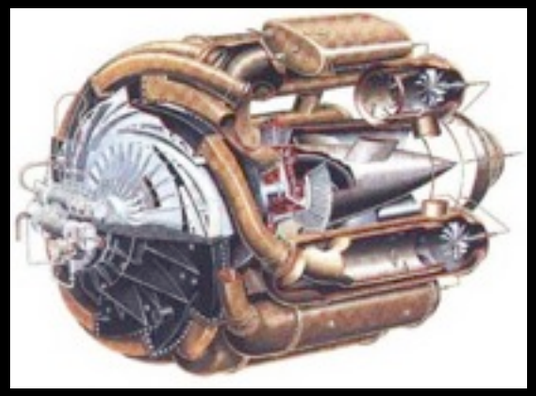

Optimization goal

Maximize compression

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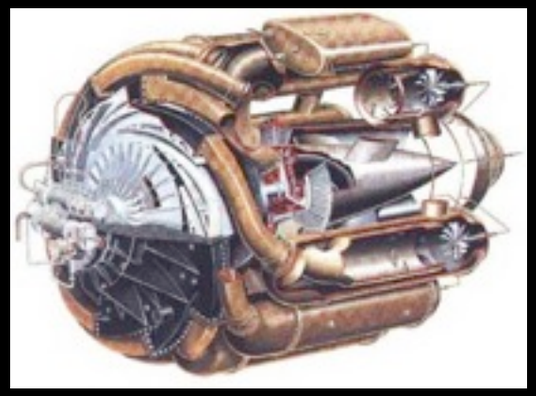

Optimization goal

Maximize compression

Minimize fuel consumption

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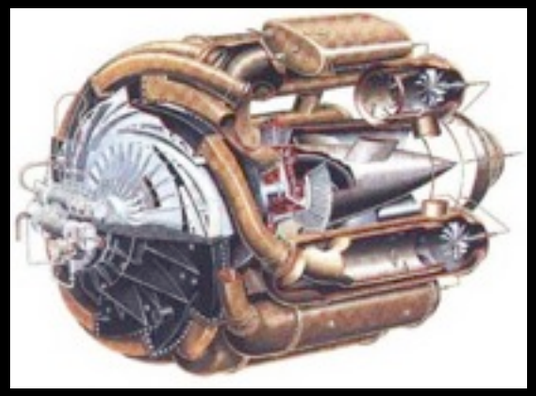
Traditional Engineering Artifact	Optimization goal	Fitness computed on a representation
	Maximize compression Minimize fuel consumption	

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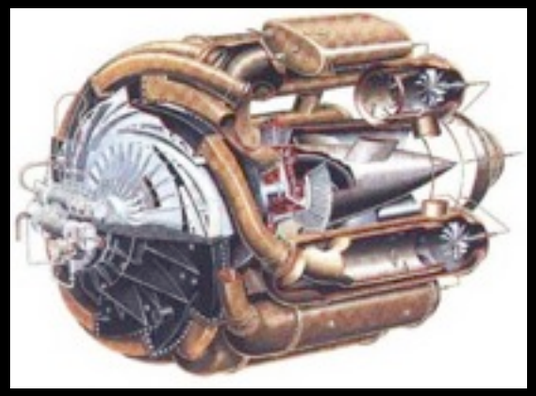

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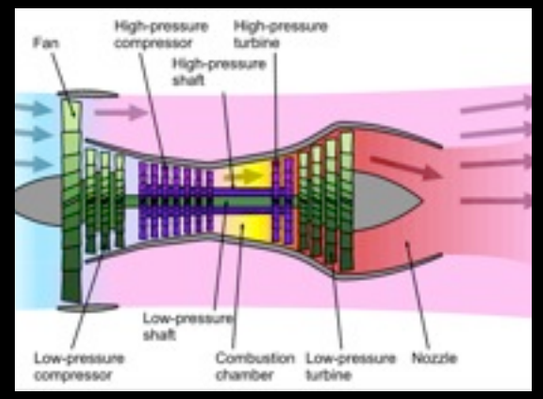

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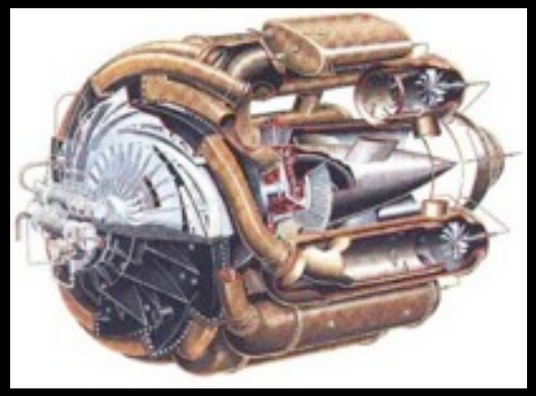

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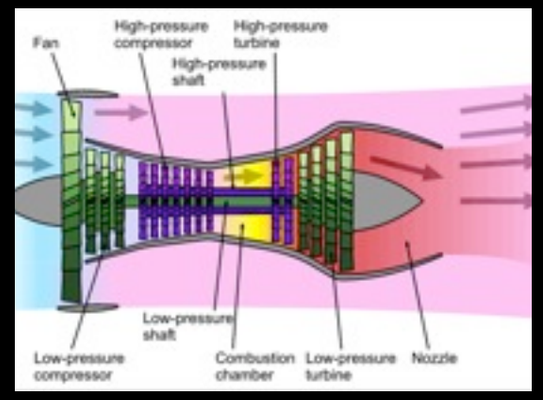

Software Engineering Artifact

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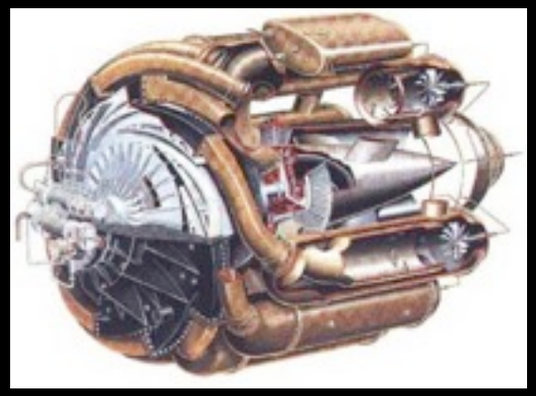
Traditional Engineering Artifact



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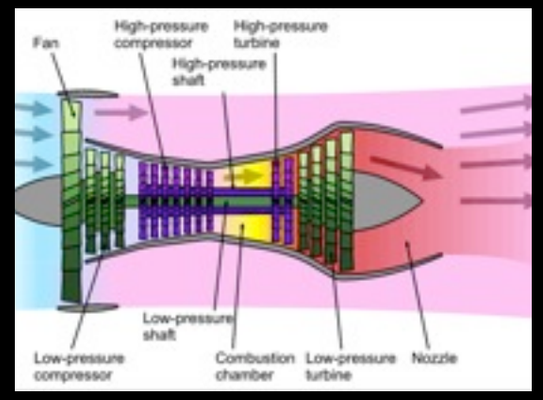

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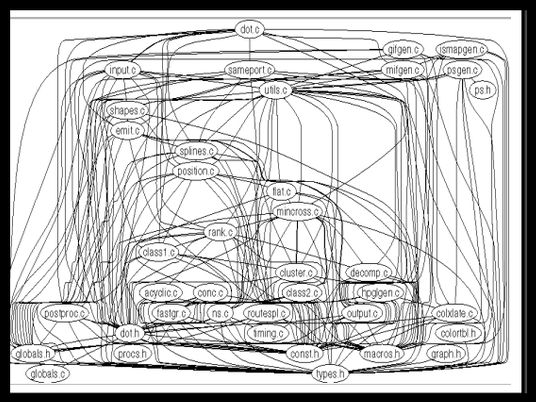

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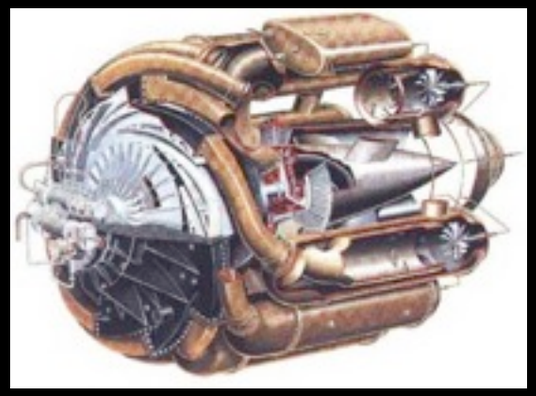

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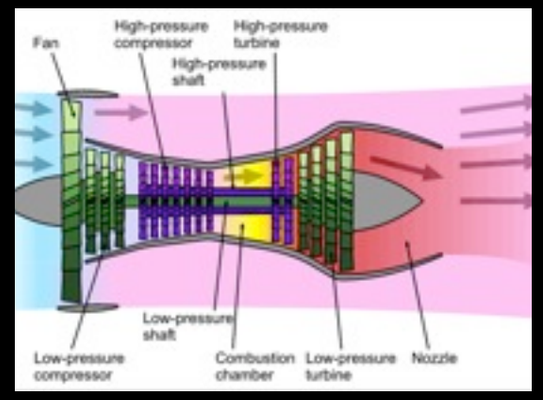
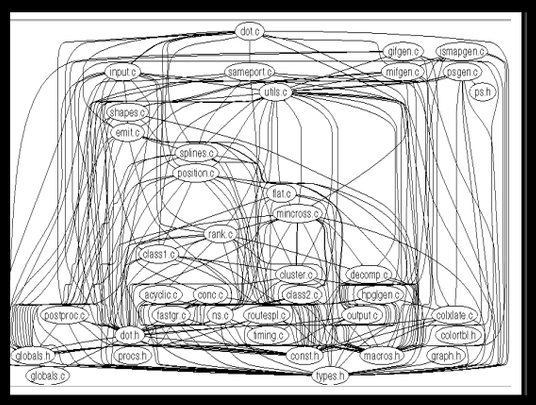
Fitness computed on a representation



Software Engineering Artifact



Optimization goal

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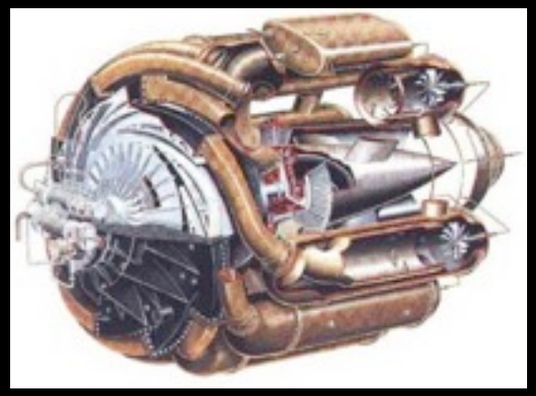
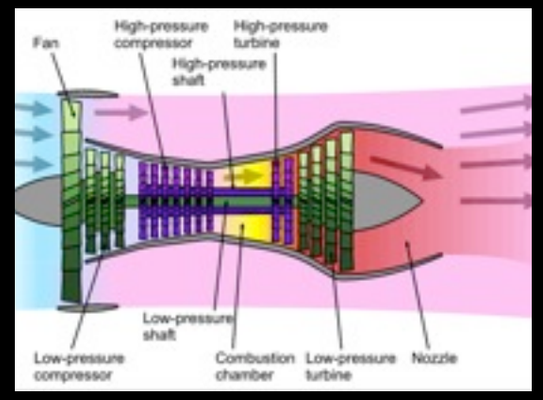
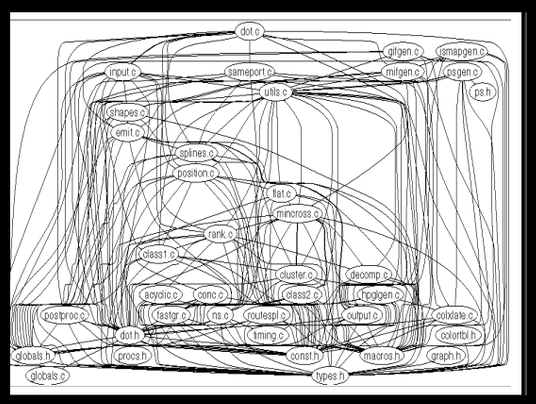
Traditional Engineering Artifact	Optimization goal	Fitness computed on a representation
	Maximize compression Minimize fuel consumption	

Software Engineering Artifact	Optimization goal
	Maximize cohesion

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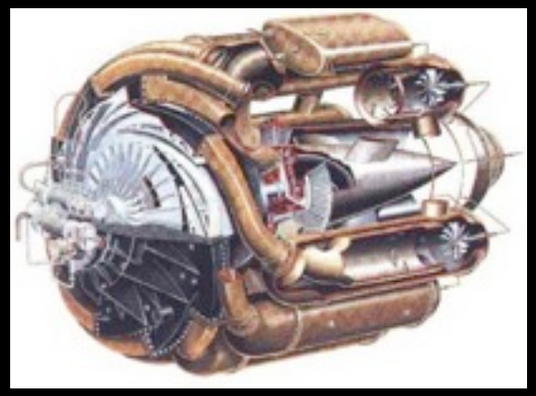
Traditional Engineering Artifact



Optimization goal

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Minimize fuel consumption

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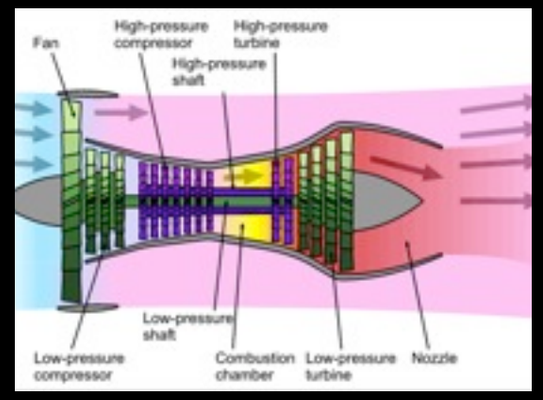

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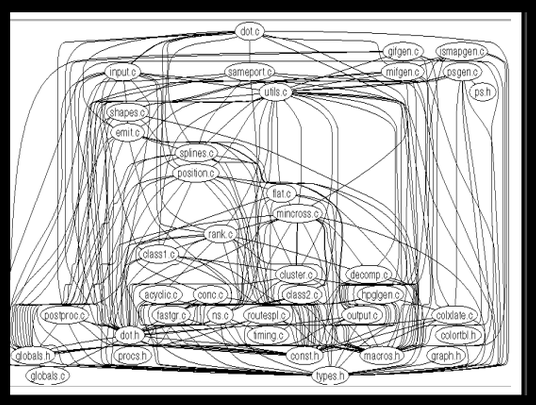

Optimization goal

Maximize cohesion

Minimize coupling

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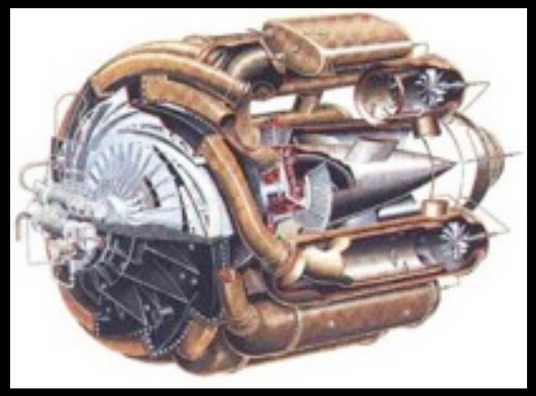

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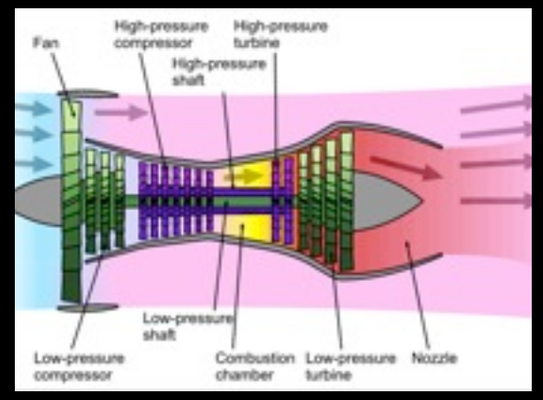

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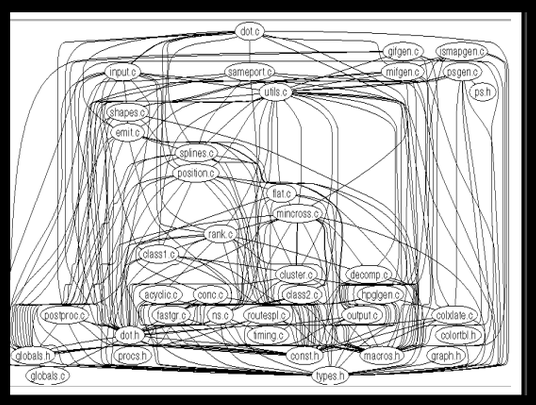

Optimization goal

Maximize cohesion

Minimize coupling

Fitness computed Directly

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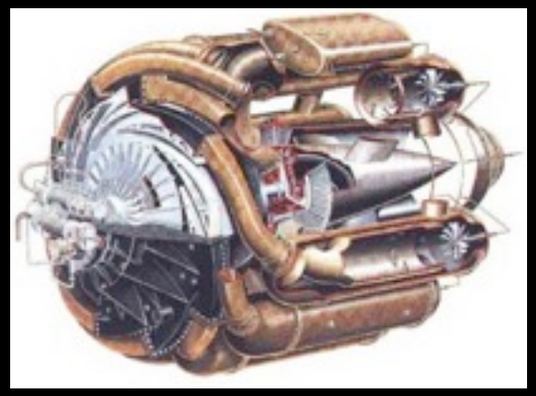

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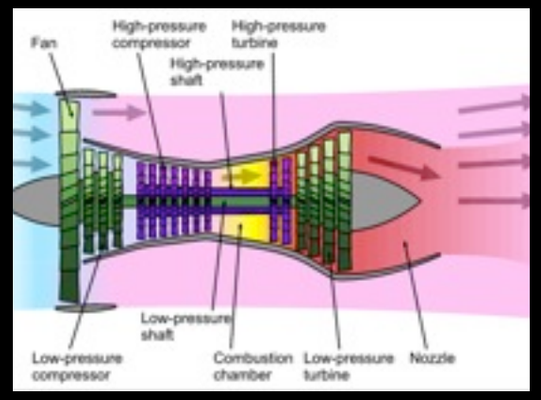

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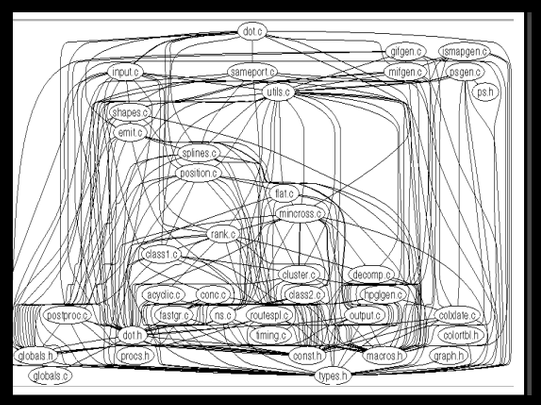

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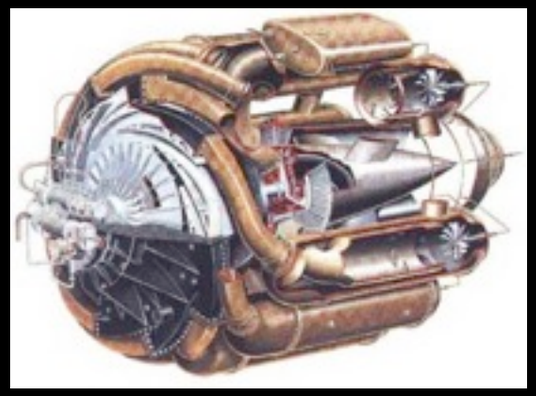

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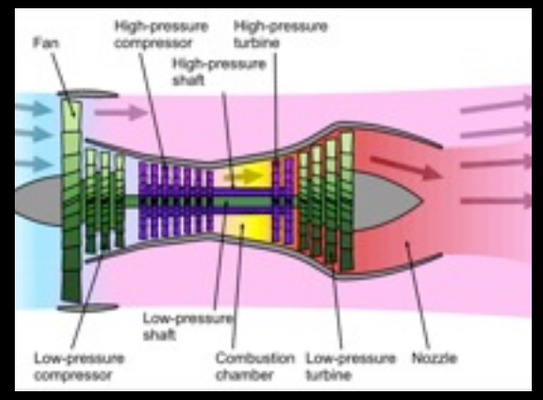

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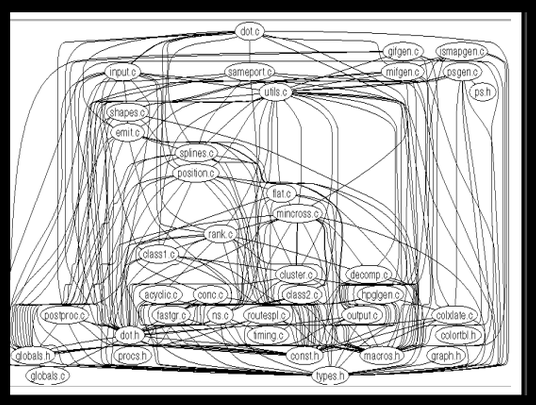

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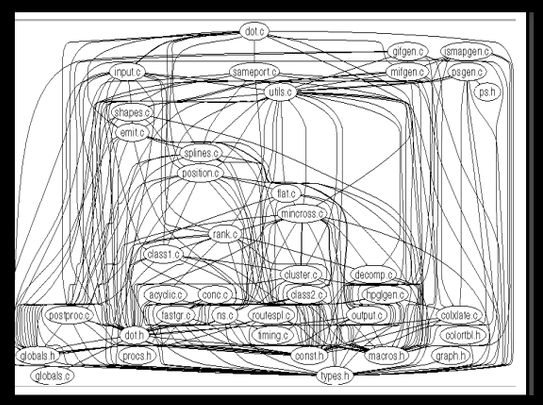

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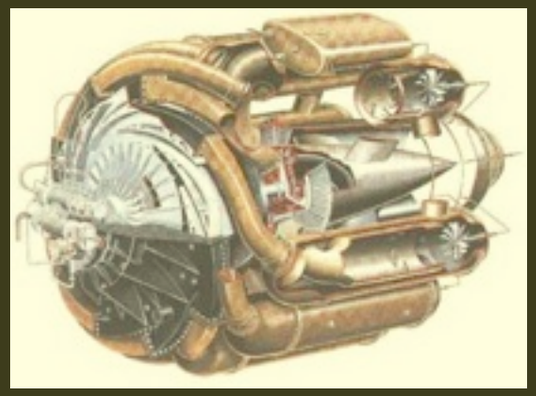

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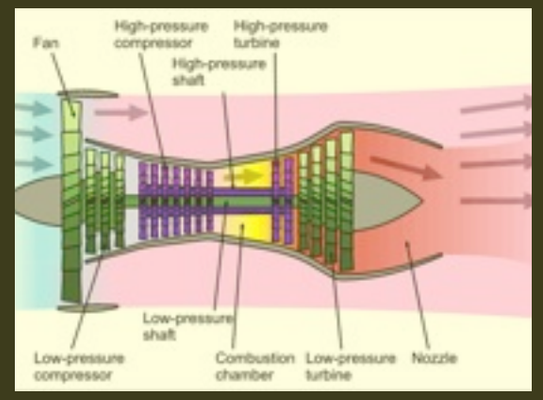

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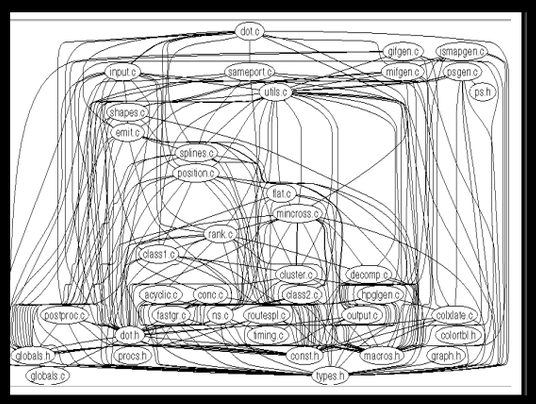

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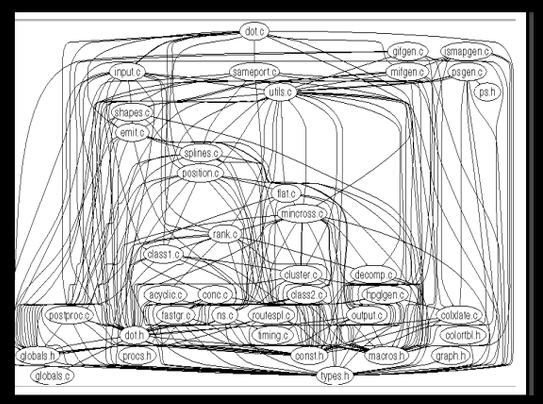

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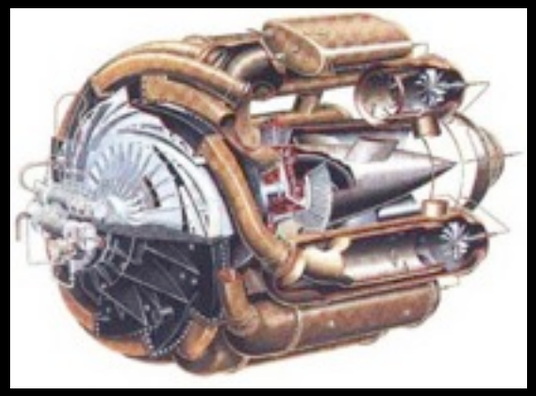

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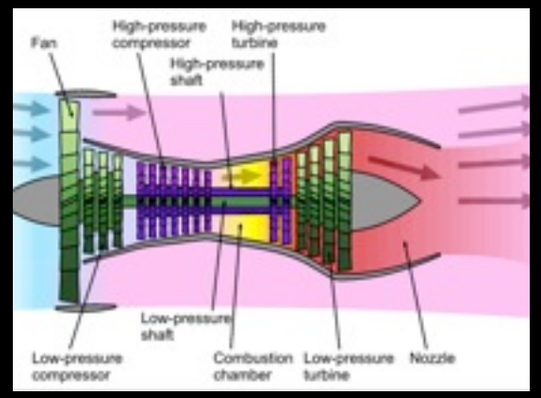

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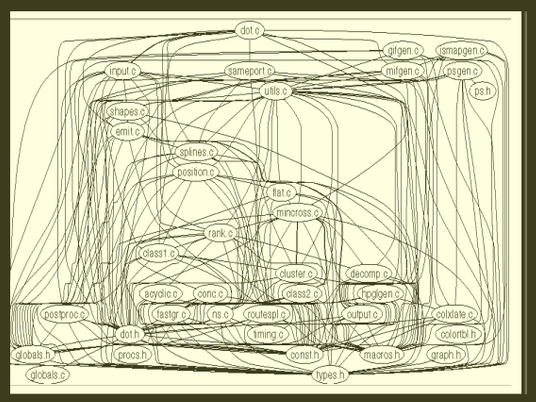

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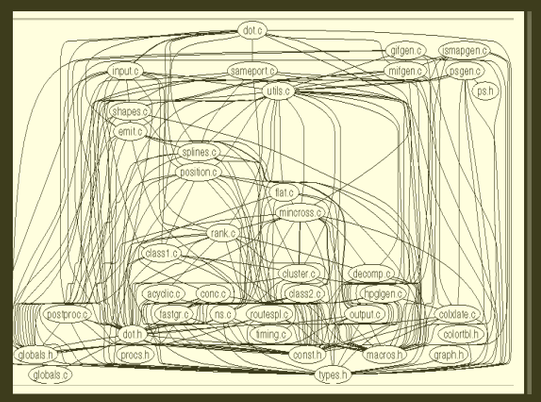

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1. Rudi Lutz: Evolving Good Hierarchical Decompositions of Complex Systems. Journal of Systems Architecture, Vol. 47(7), pp. 613-634, 2001.
2. Robert Feldt, Richard Torkar, Tony Gorschek & Wasif Afzal: Searching for Cognitively Diverse Tests: Test Variability and Test Diversity Metrics. Proceedings of 1st International Workshop on Search-Based Software Testing (SBST) in conjunction with ICST 2008, pp. 178-186, Lillehammer Norway. Best paper award winner

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Conclusion

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Mark Harman: The current state and future of SBSE
ICSE 2007 Future of Software Engineering paper.

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Overviews and Survey Paper

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extra slides ...

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sensitivity analysis ...

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Sensitivity analysis

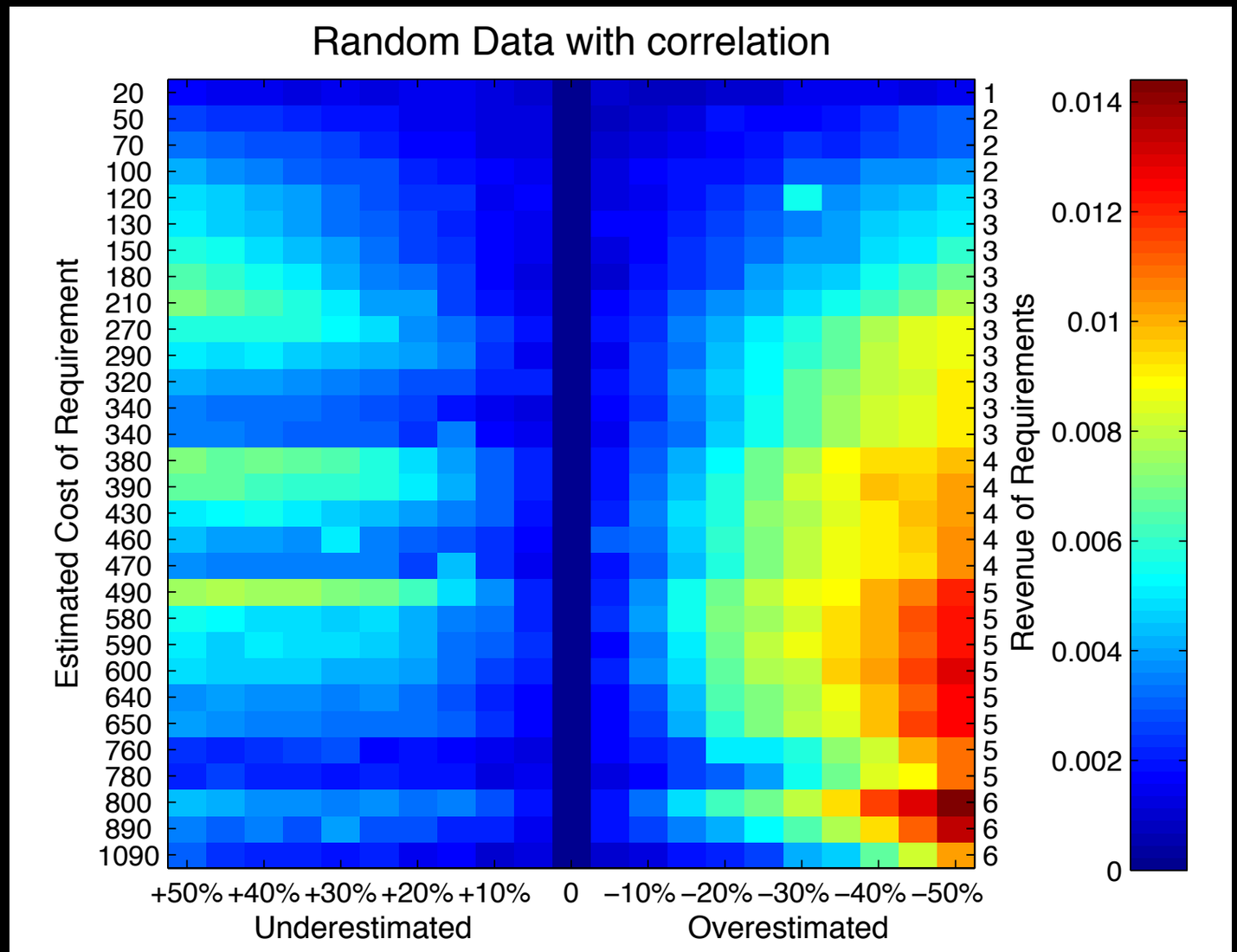
Inputs to search are typically estimates

Estimated Software Engineering attributes

Which estimates matter most?

Applied to component selection ...

Motorola Cell Phone Requirements



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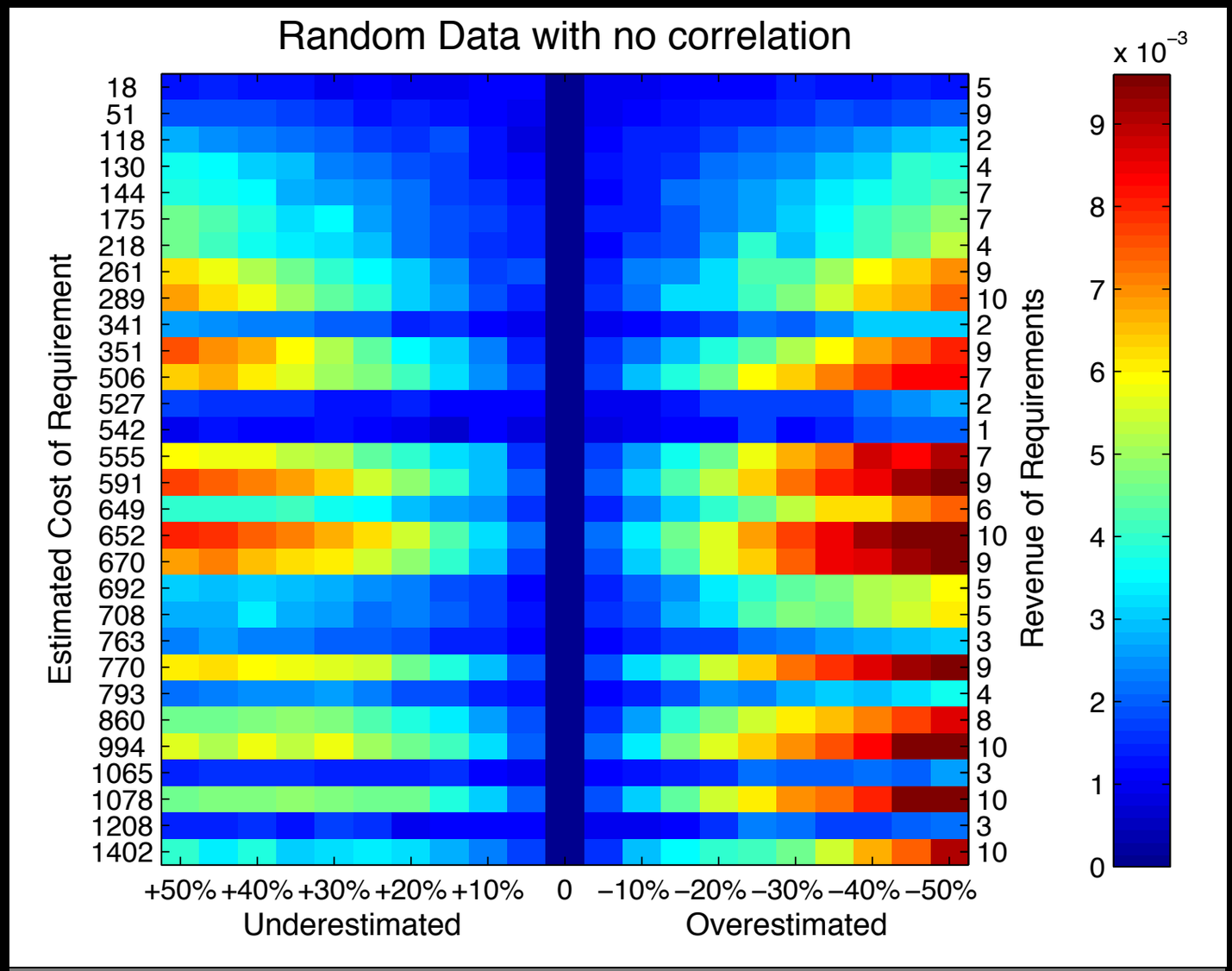

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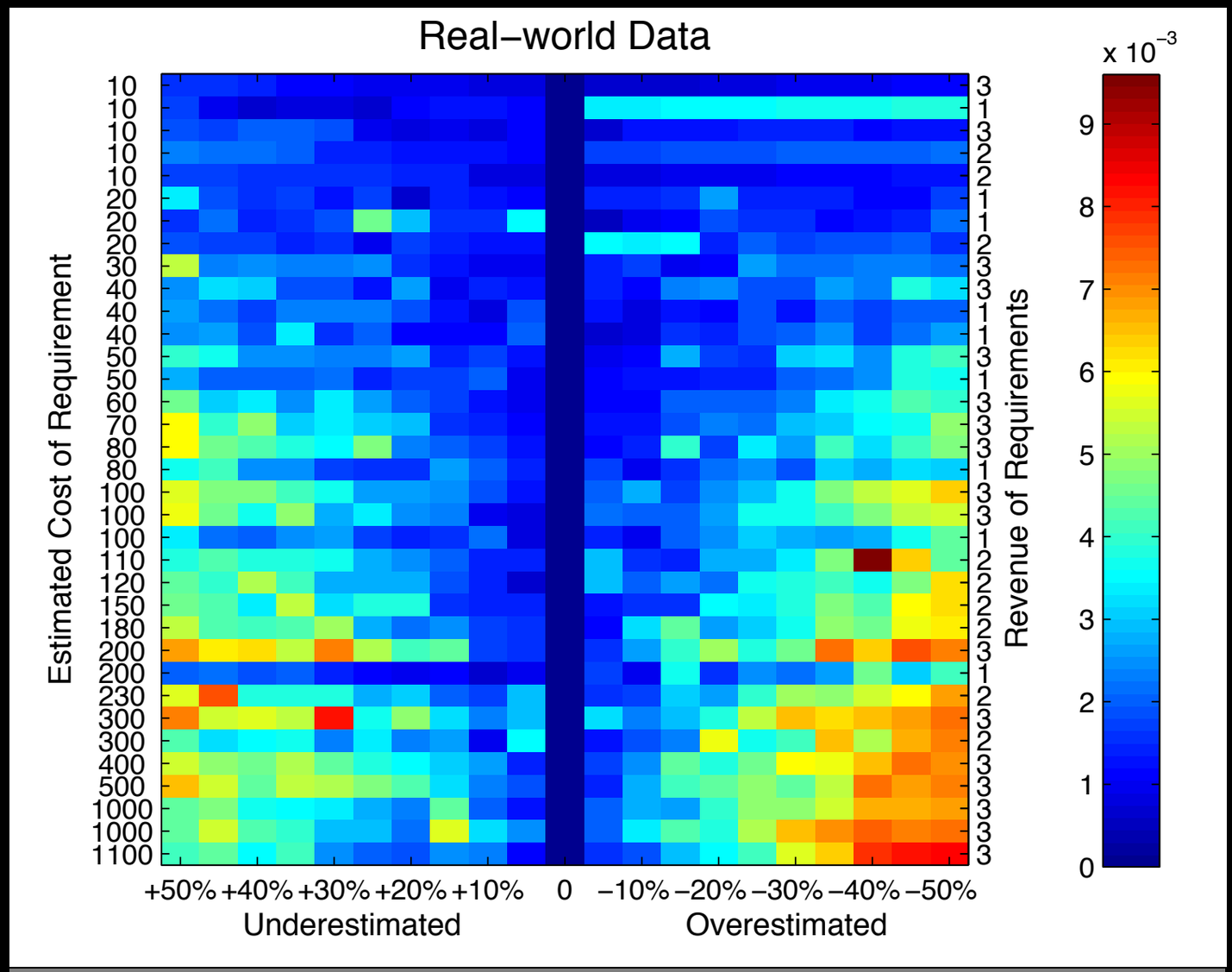

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for mutation testers

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Co Evolution

Two populations; Two fitness functions

Collaboration, and competition

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Co Evolution

Two populations; Two fitness functions

Collaboration, and competition

We have applied this to mutation testing ...

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```
Main(){
  …
  c = a + b ;
  …
}
```

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```
Main(){
 …
 c = a + b ;
 …
}
```

```
Main(){
 …
 c = a - b ;
 …
}
```

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```
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 c = a + b ;
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```

```
Main(){
 …
 c = a - b ;
 …
}
```

```
Main(){
 …
 c = a && b ;
 …
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```

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}
```

```
Main(){
 …
 c = a * b ;
 …
}
```

```
Main(){
 …
 c = a + b ;
```

```
Main(){
 …
 c = a - b ;
 …
}
```

```
Main(){
 …
 c = a && b ;
 …
}
```

```
 …
 c = a * b ;
 …
}
```

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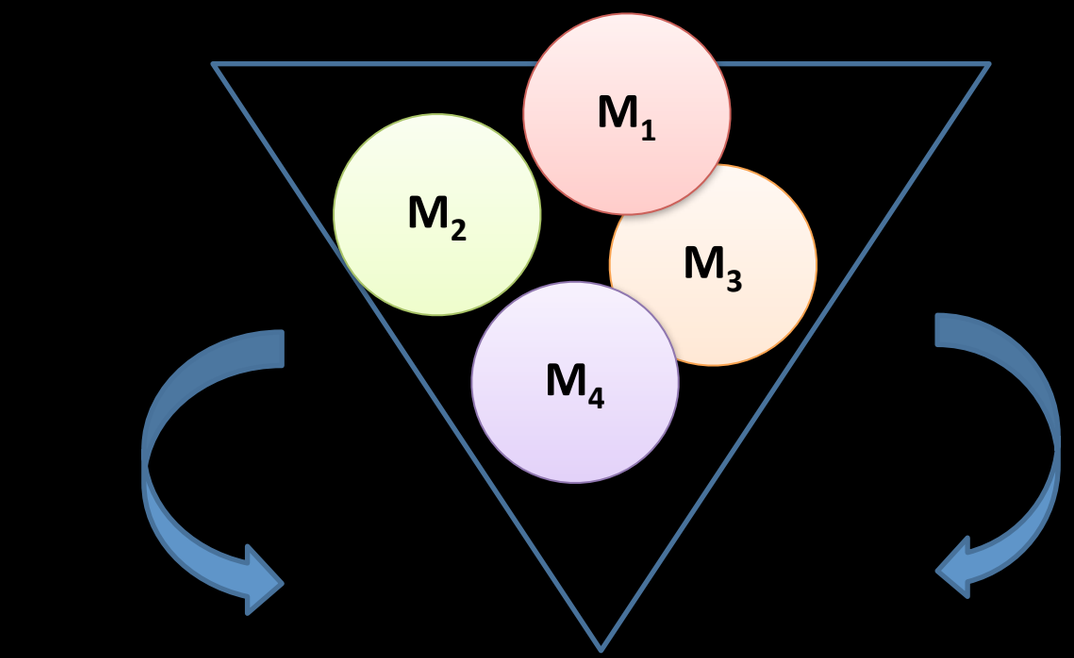
```
Main(){
 …
 c = a + b ;
```

```
Main(){
 …
 c = a - b ;
 …
}
```

```
Main(){
 …
 c = a && b ;
 …
}
```

```
 …
 c = a * b ;
 …
}
```



Killed
(Different result)

Survives
(Same result)

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Equivalent mutant

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Equivalent mutant

```
Main(){
  …
  c = a + b ;
  …
}
```

Equivalent mutant

```
Main(){
  …
  c = a + b ;
  …
}
```

Equivalent mutant

```
Main(){
  …
  c = a + b ;
  …
}
```

```
Main(){
  …
  c = a + b ;
  …
}
```

Equivalent mutant

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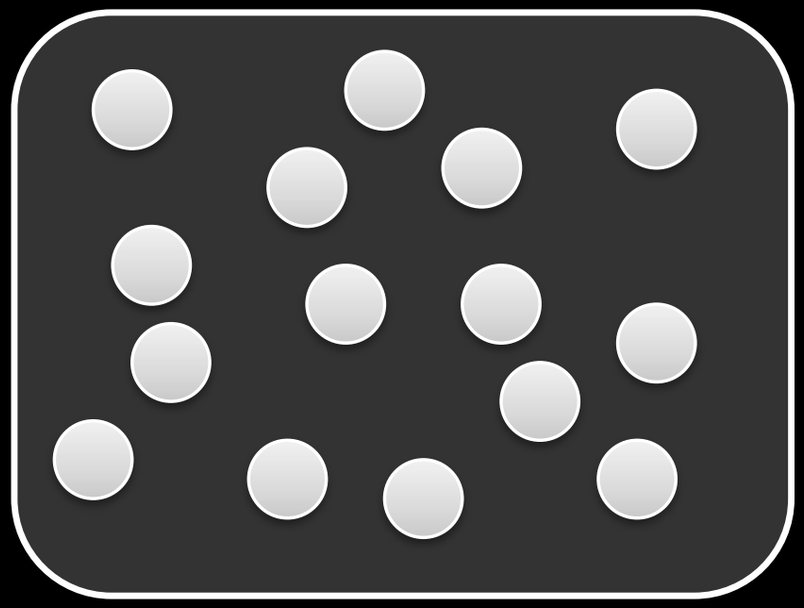
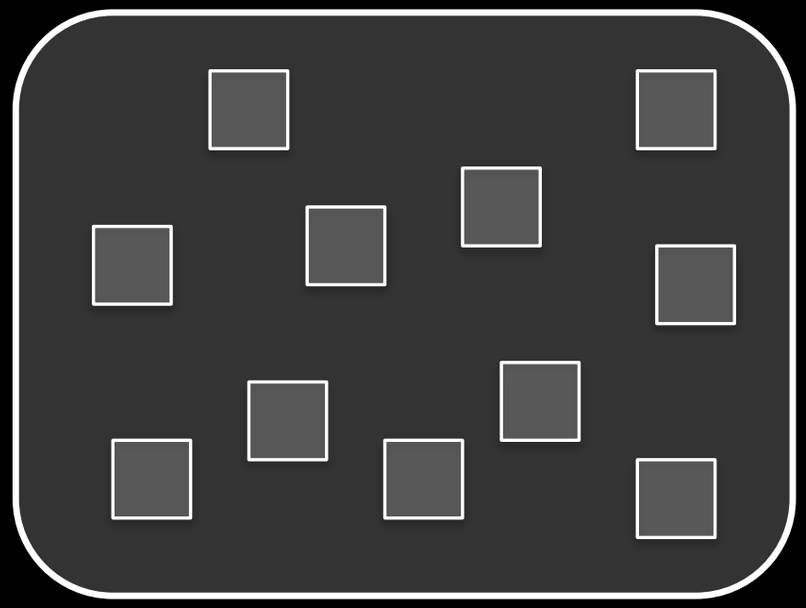


Mutants



Test set

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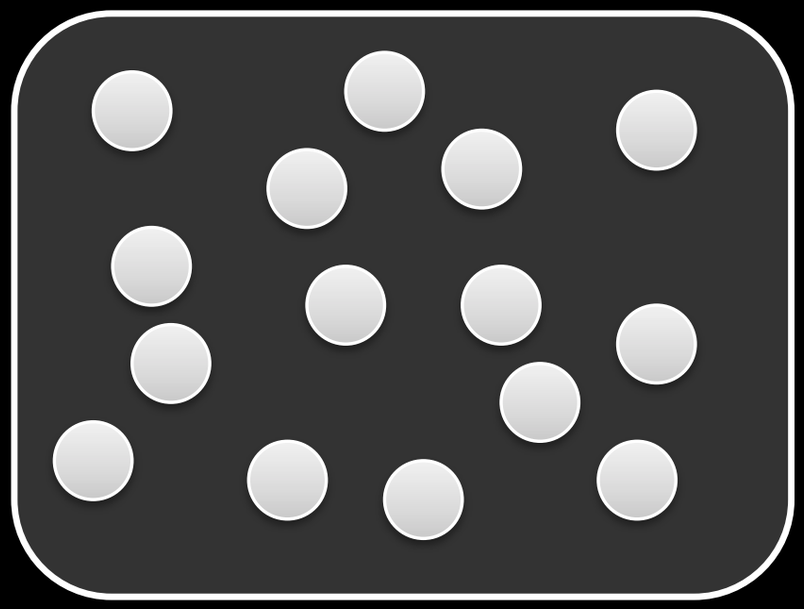
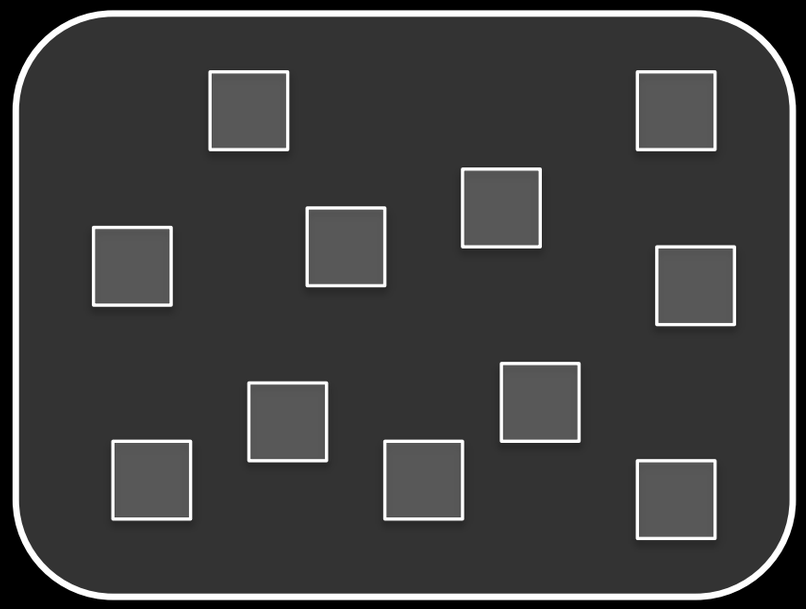
Fitness?



Mutants



Test set

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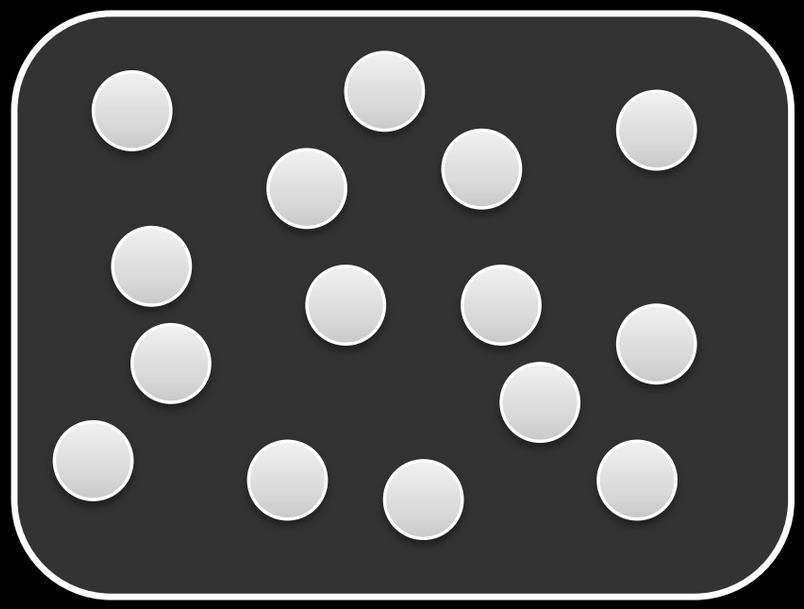
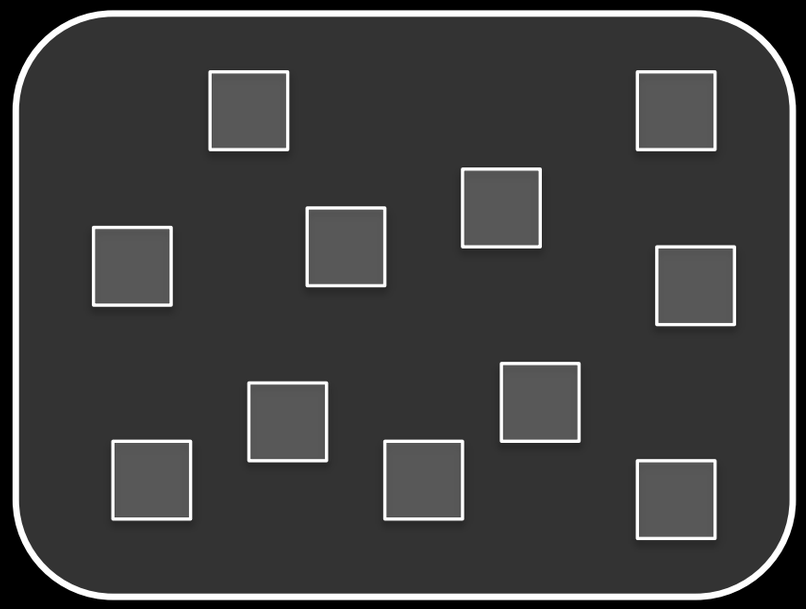
Fitness for test cases

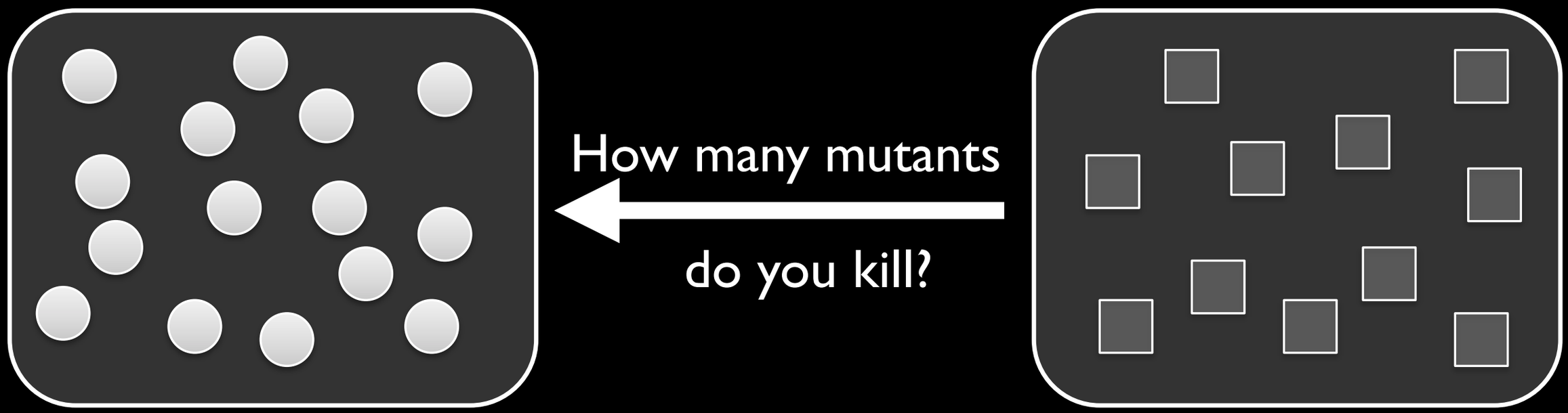


Mutants

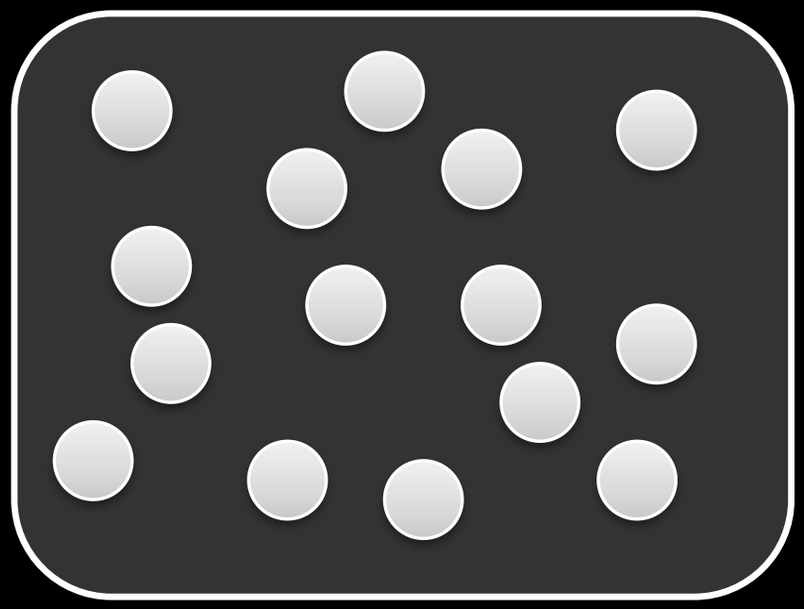


Test set

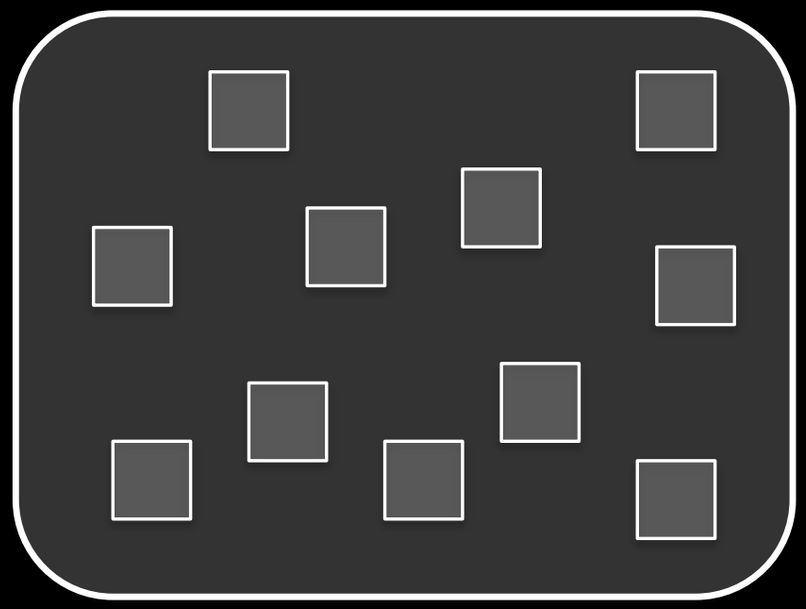
Fitness for test cases



Fitness for mutants



Mutants



Test set

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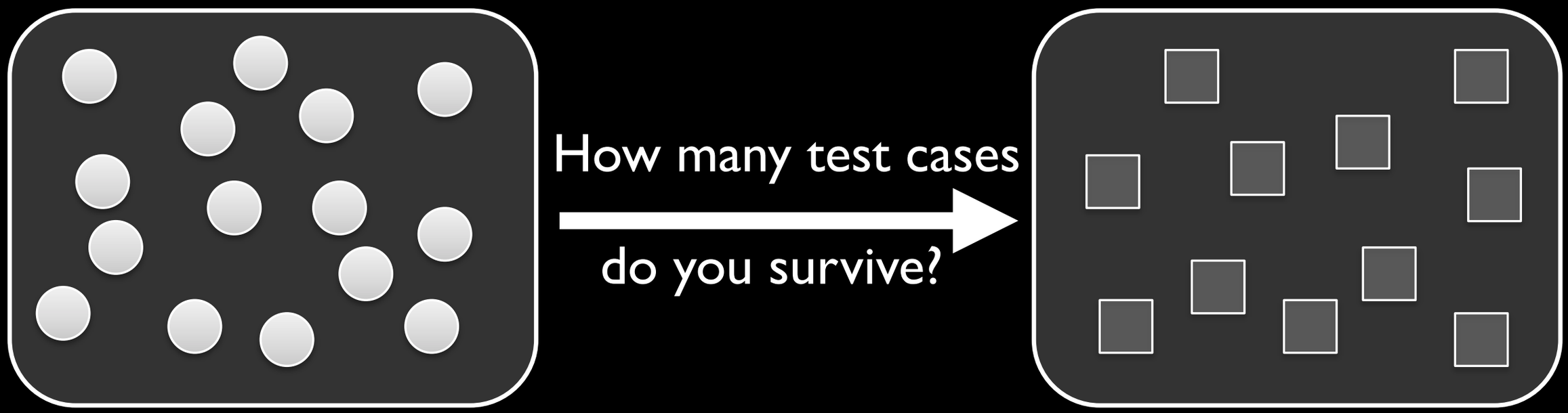
Fitness for mutants



Mutants

Test set

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for HCI, comprehension, psychologists

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Possibilities

Let's allow ourselves to think wide and wild

With SBSE we are only bounded by imagination

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Possibilities

Let's allow ourselves to think wide and wild

With SBSE we are only bounded by imagination

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Co Evolution

Two populations; Two fitness functions

Collaboration, and competition

Could it be applied to cognitive modelling...

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Cognitive Model

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Cognitive Model

Performance

at finding information

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Cognitive Model

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Cognitive Model

Performance

at hiding information

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SBSE for HCI?

Co Evolve cognitive models

Evolve architectures

Evolve interfaces

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SBSE for HCI?

Co Evolve cognitive models

Evolve architectures

Evolve interfaces

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Architecture

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Which architecture is best?

Multiple developers = multiple objectives

Explore space of developer dissonance

Can apply to any shared endeavour

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SBSE for HCI?

Co Evolve cognitive models

Evolve architectures

Evolve interfaces

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SBSE for HCI?

Co Evolve cognitive models

Evolve architectures

Evolve interfaces

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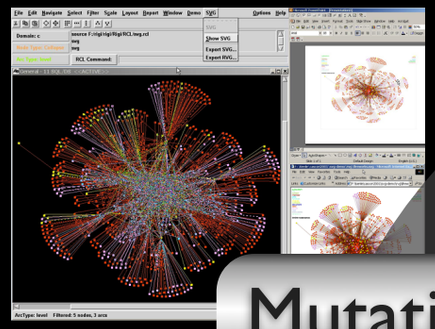
Evolution of interfaces



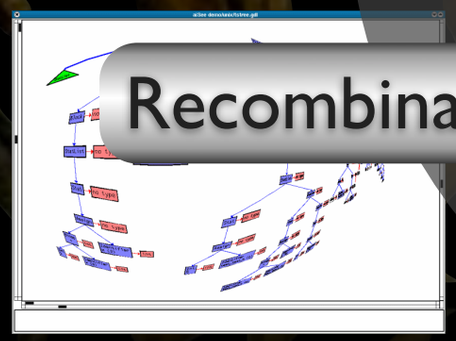
Mutation

Insertion

Test cases

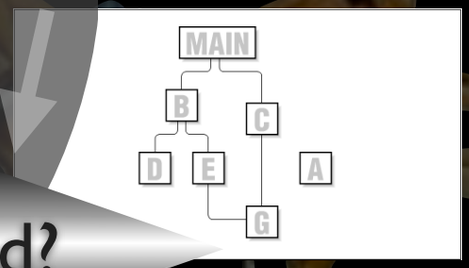
Execution

Fitness evaluation

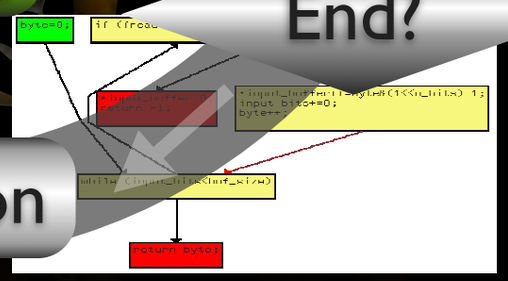


Recombination

Monitoring



End?



Selection

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for formalists and testers

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Scientists' and Engineers' viewpoints

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Scientists' and Engineers' viewpoints

Scientist:

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Scientists' and Engineers' viewpoints

Scientist:

what is true

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Scientists' and Engineers' viewpoints

Scientist:

what is true correctness

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Scientists' and Engineers' viewpoints

Scientist:

what is true

correctness

model the world

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Scientists' and Engineers' viewpoints

Scientist:

what is true
correctness
model the world
to understand

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Scientists' and Engineers' viewpoints

Scientist:

what is true

model the world

to understand

Engineer:

correctness

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Scientists' and Engineers' viewpoints

Scientist:

what is true

correctness

model the world

to understand

Engineer:

what is possible

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Scientists' and Engineers' viewpoints

Scientist:

what is true

correctness

model the world

to understand

Engineer:

what is possible

within tolerance

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Scientists' and Engineers' viewpoints

Scientist:

what is true
correctness
model the world
to understand

Engineer:

what is possible
within tolerance
model the world

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Scientists' and Engineers' viewpoints

Scientist:

what is true
correctness
model the world
to understand

Engineer:

what is possible
within tolerance
model the world
to manipulate

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Scientists' and Engineers' viewpoints

Computer Scientist:	Software Engineer:
what is true	what is possible
about computation	with software
prove correctness	test for imperfection
make it perfect	find were to improve

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Combing Science and Engineering

prove correctness
make it perfect

test for imperfection
find were to improve

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Combing Science and Engineering

prove correctness
make it perfect

test for imperfection
find were to improve

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Combing Science and Engineering

prove correctness
make it perfect

where possible ...
... and where impossible ...

test for imperfection
find were to improve

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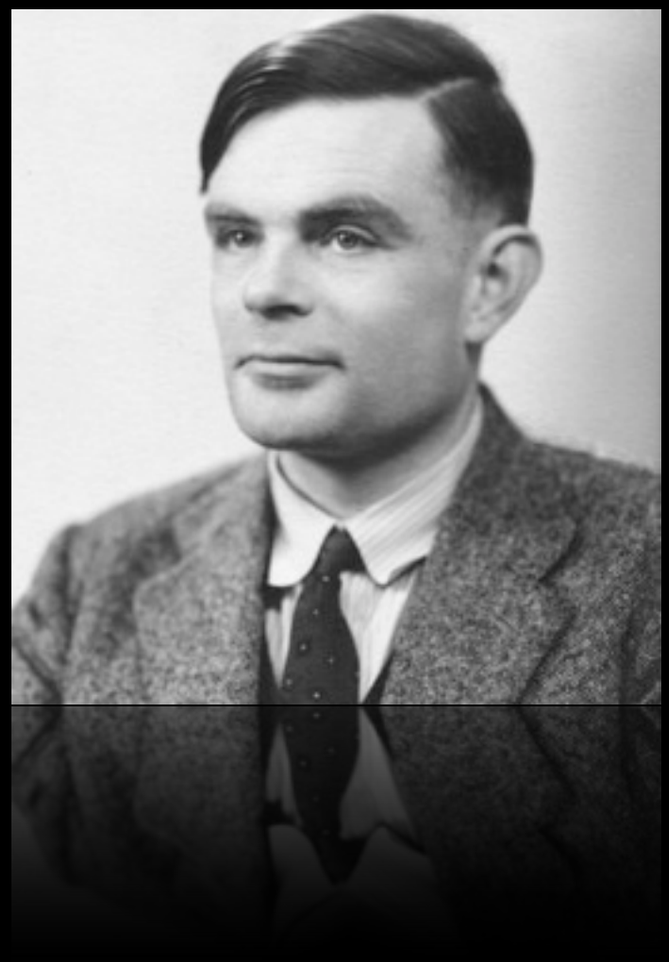
Alan Turing? First tester?



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Alan Turing? First tester?

Alan M. Turing: Checking a Large Routine
Report of a Conference on High Speed Automatic Calculation Machines pp67-69, 1949

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Alan Turing? First tester?

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Ugh was the world's first tester

Ugh was the first system tester in 2,600 BC

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Stonehenge: first computer?

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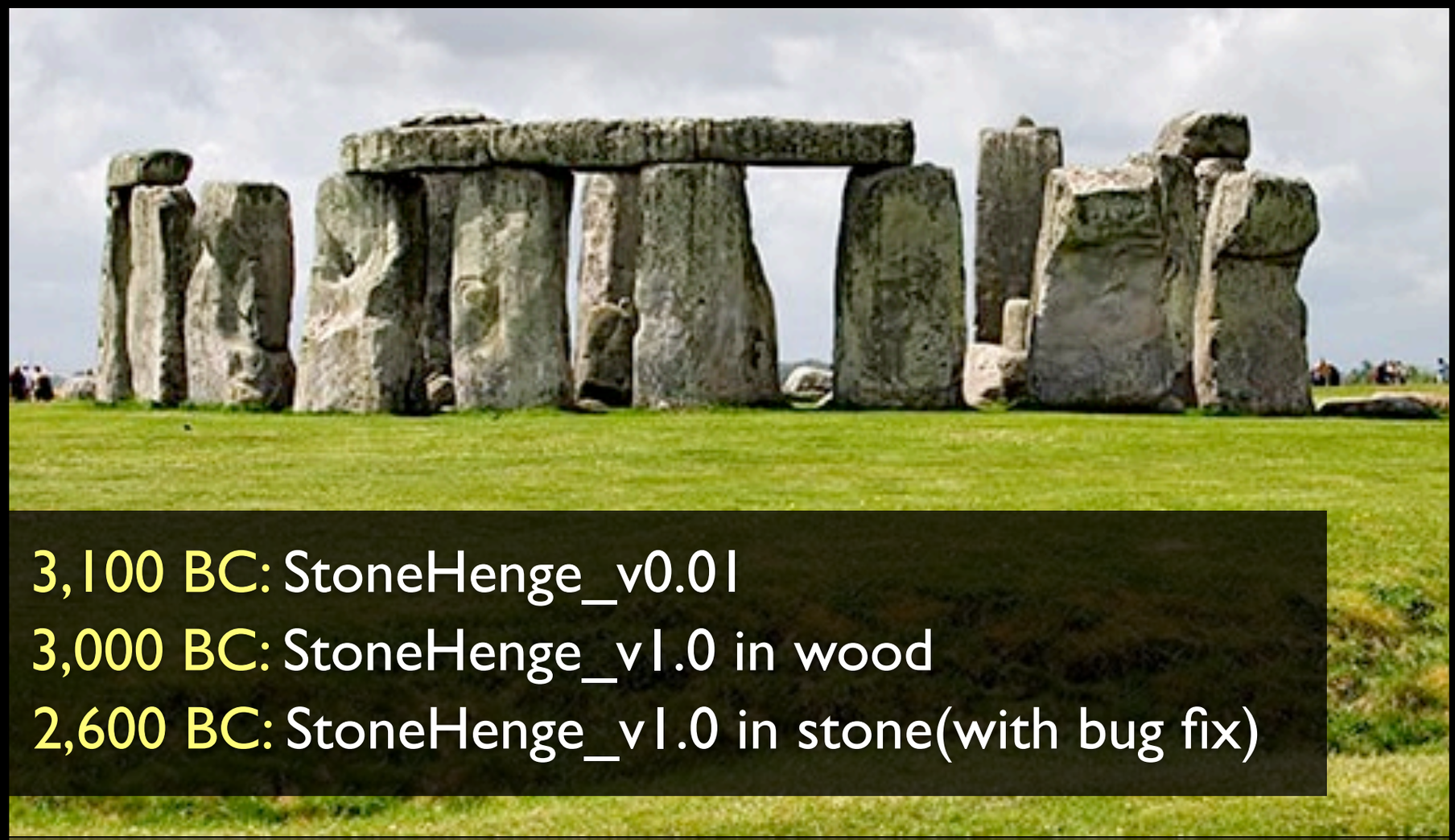
Stonehenge: first computer?



3,100 BC: StoneHenge_v0.01
3,000 BC: StoneHenge_v1.0 in wood
2,600 BC: StoneHenge_v1.0 in stone(with bug fix)

Stonehenge: first computer?

3,100 BC: StoneHenge_v0.01

3,000 BC: StoneHenge_v1.0 in wood

2,600 BC: StoneHenge_v1.0 in stone(with bug fix)

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Stonehenge: first computer?

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