Accuracy-Aware Program Transformations

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Joint work with
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Trend #1: Computations operate on enormous data sets

Process not all but just enough data

Trend #2: Big computations never execute perfectly

Enable programs to adapt and keep executing

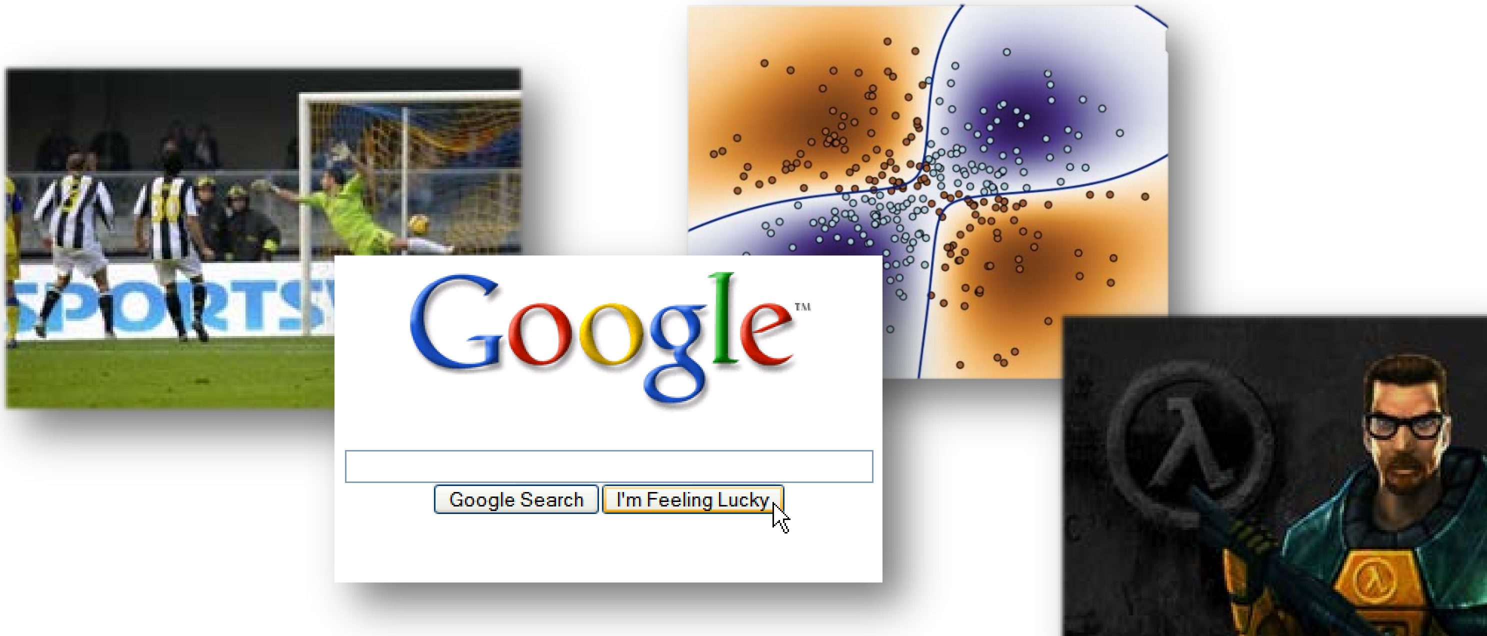
Trend #3: Huge space of alternative computations

Automate the process

Current paradigm of perfect software does not account for these trends

Calls for a new paradigm!

Approximate Computations



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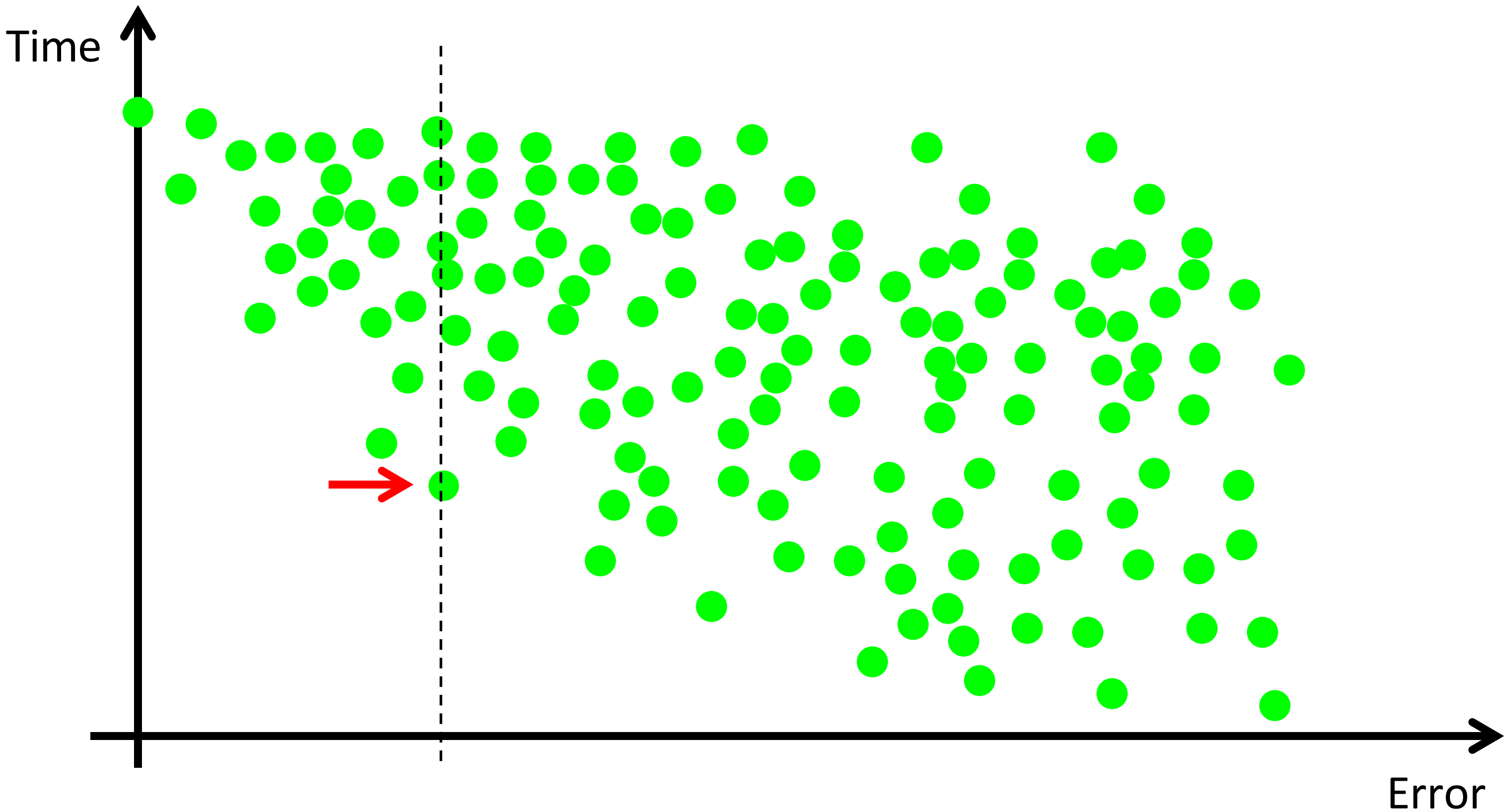
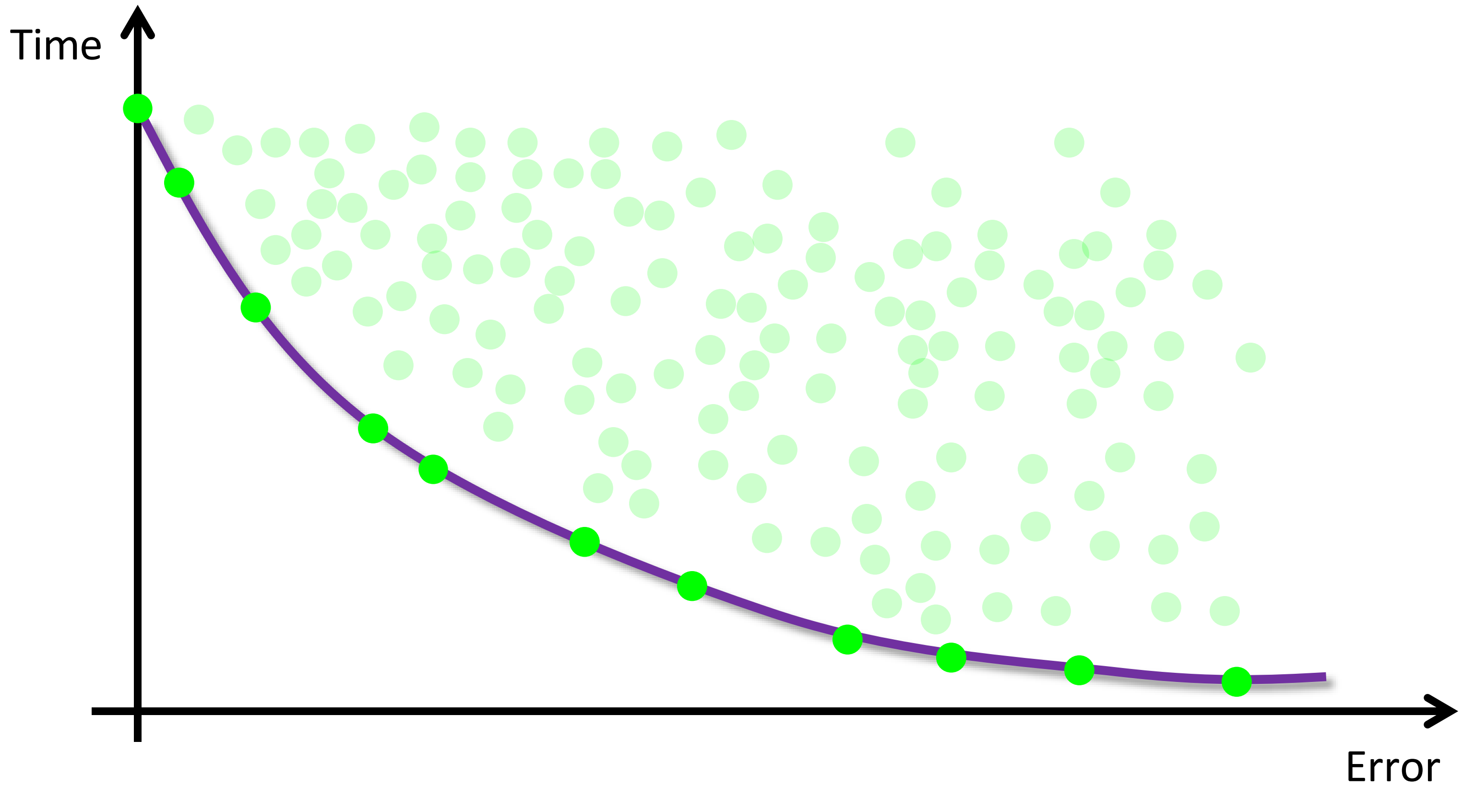
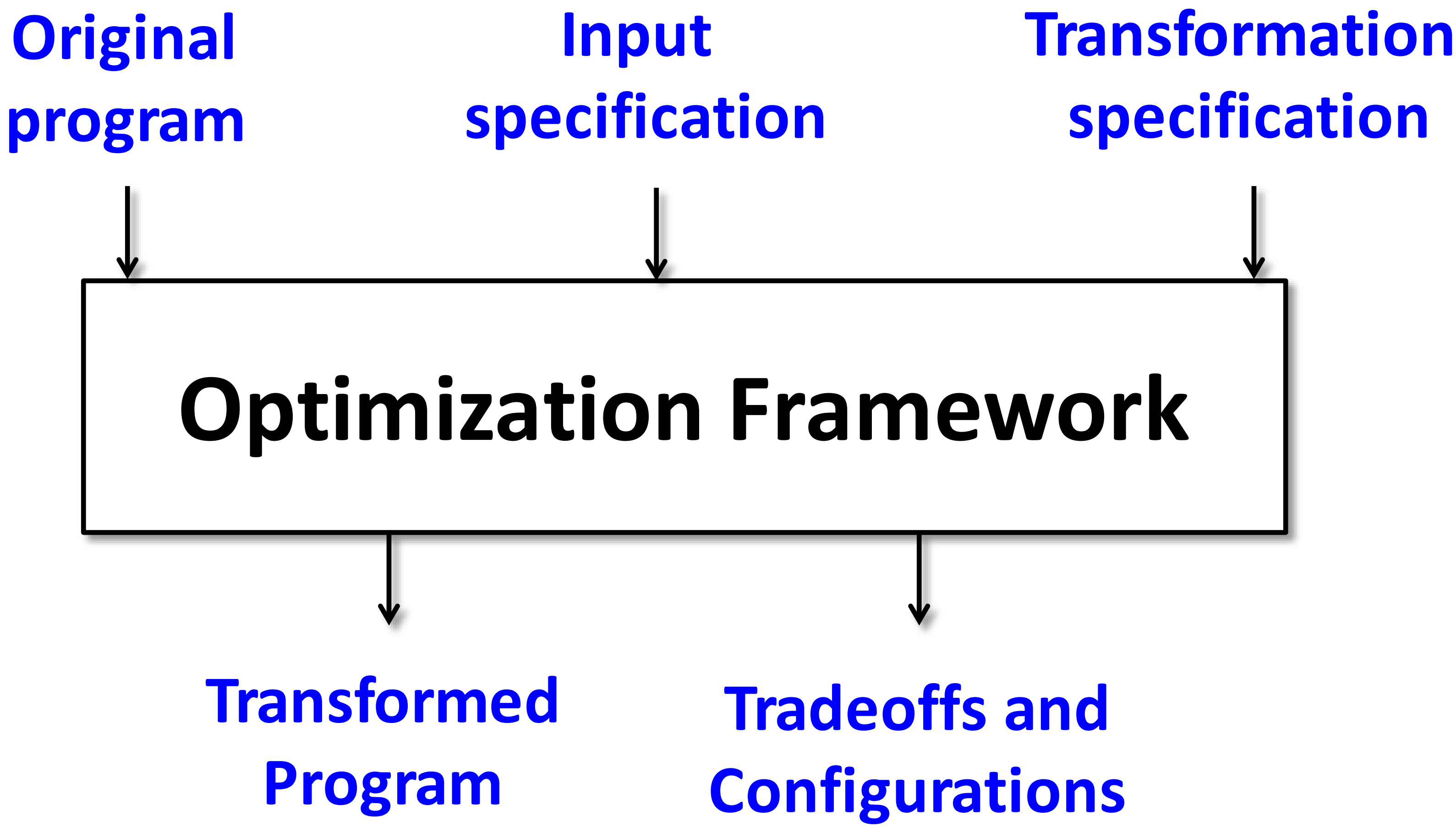
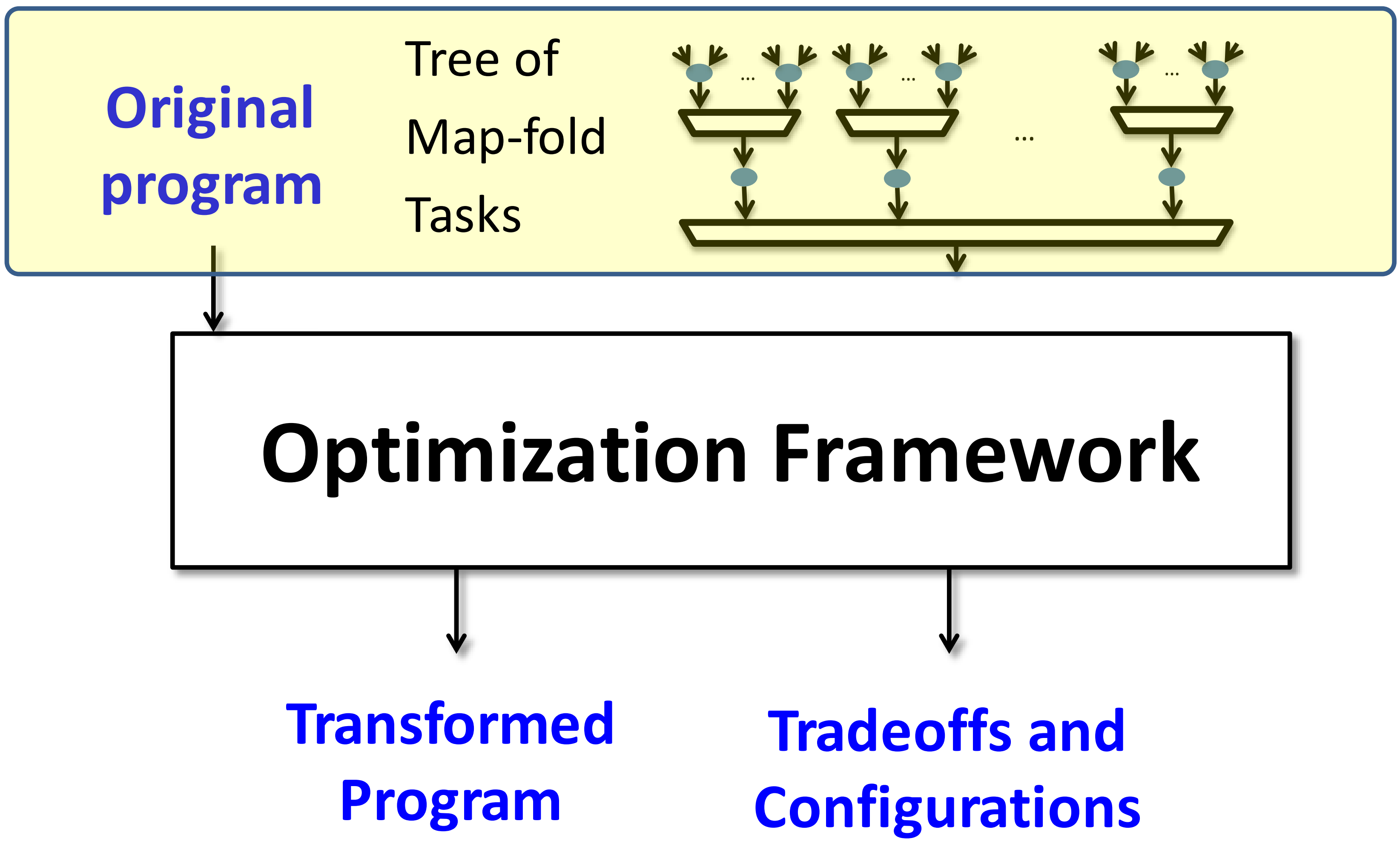
Tradeoff Space



Tradeoff Space




Original
program
Input
specification
Transformation
specification
Optimization Framework
Transformed
Program
Tradeoffs and
Configurations


Original program
Tree of
Map-fold
Tasks
...
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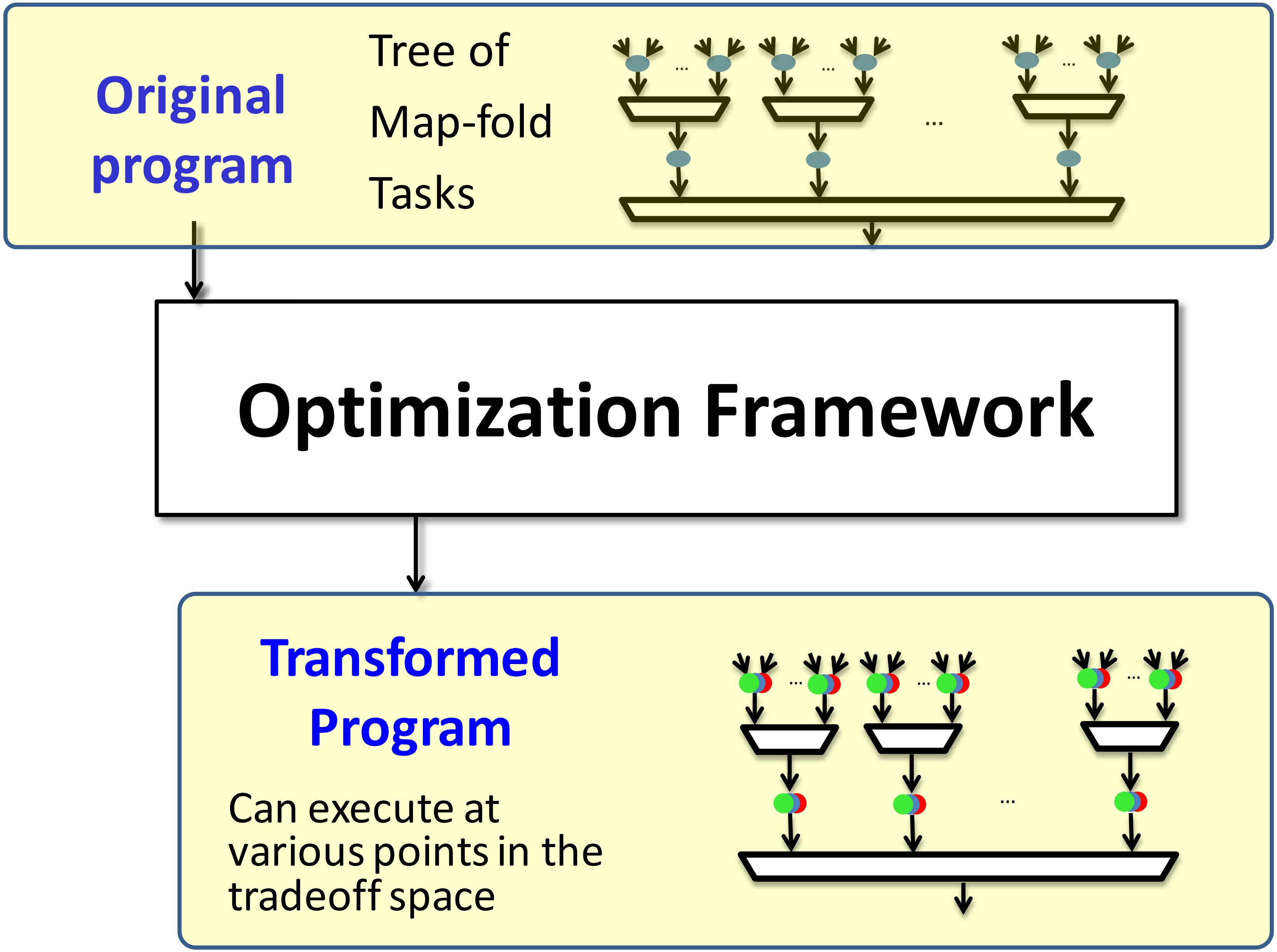
Original program
Tree of
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...
Optimization Framework
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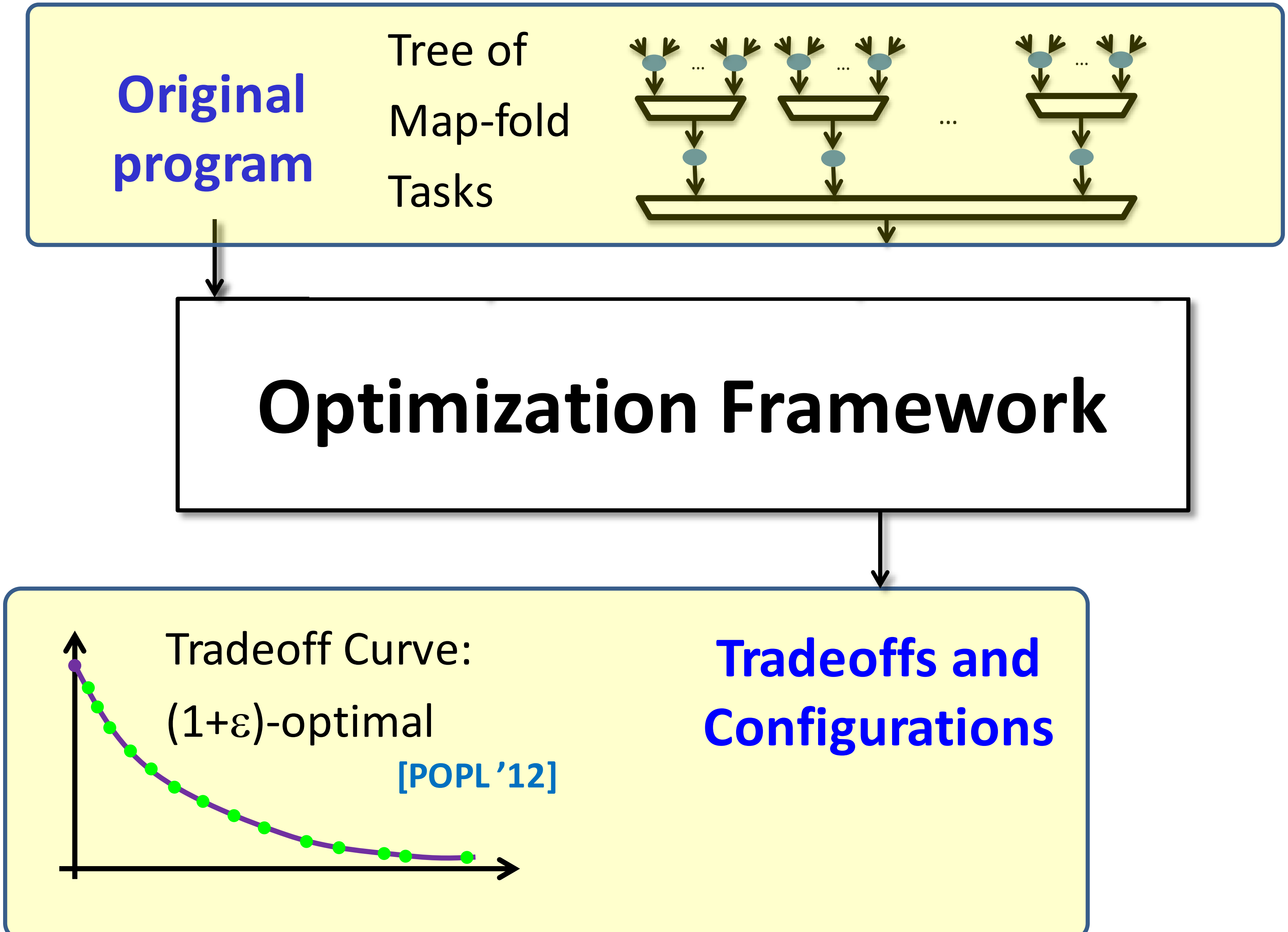
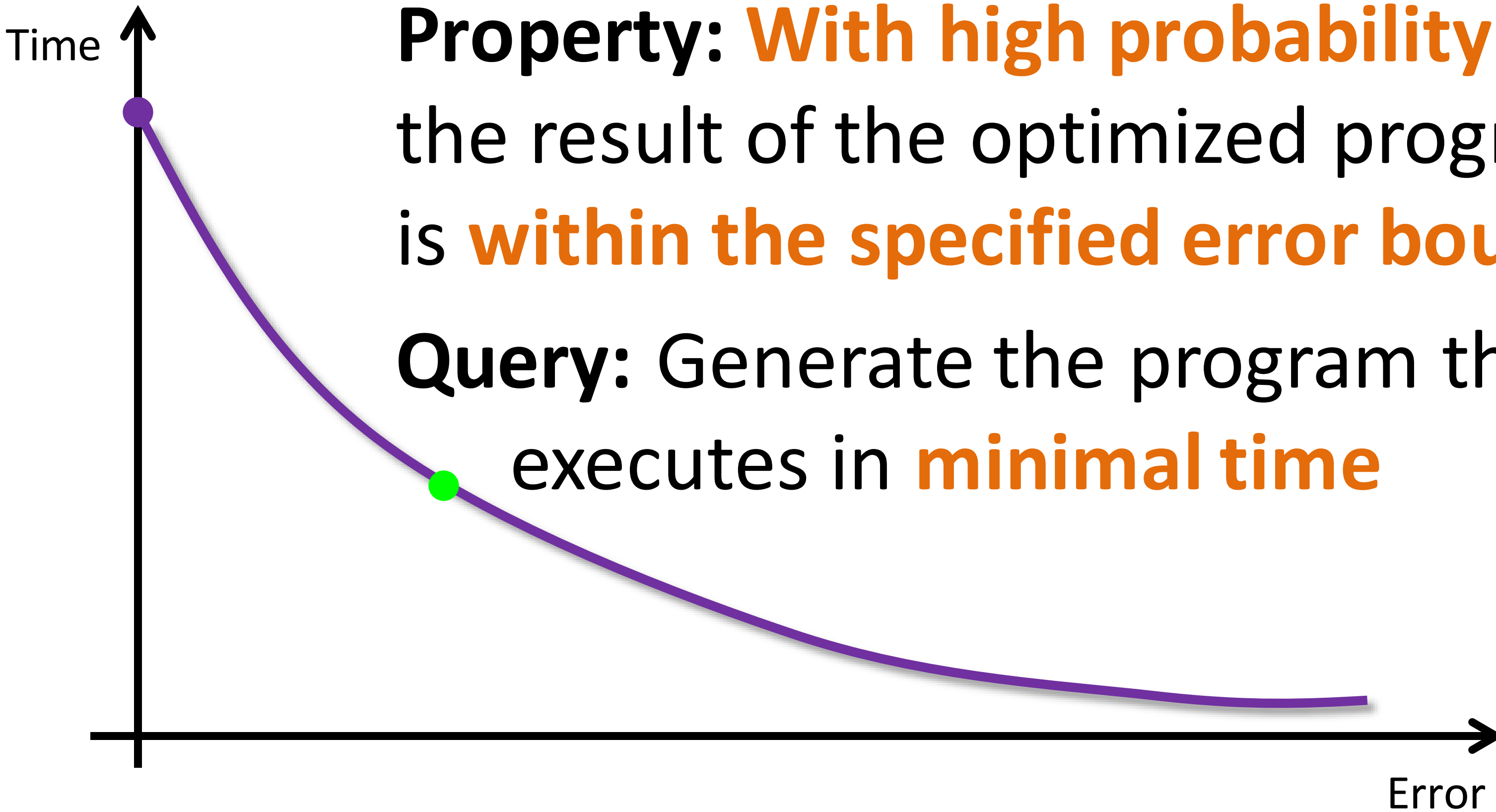
Program
Can execute at
various points in the
tradeoff space
...



Original program
Tree of
Map-fold
Tasks
Optimization Framework
Tradeoff Curve:
(1+ε)-optimal
[POPL '12]
Tradeoffs and Configurations

Search for Optimized Programs



Property: **With high probability** the result of the optimized program is **within the specified error bound**

Query: Generate the program that executes in **minimal time**

Example: Blackscholes

```
function Blackscholes (option)
  T = option.Time
  S = option.Strike
  V = option.Volatility
  t1 = ContinuousF1 (T, S, V)
  t2 = ContinuousF2 (T, S, V)
  return ContinuousF3 ( t1, t2, option)
```

```
function main (options)
  return sum ( map Blackscholes options )
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Input specification:

- option.Strike $\in [s_0, s_1]$
- option.Time $\in [t_0, t_1]$
- option.Volatility $\in [v_0, v_1]$
- Size of options $\in [n_0, n_1]$

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Transformations:

- **Functions**: specialize implementations for expected input ranges
- Polynomial interpolation
- Transformed Computation:

```
function ContinuousF1 (·, ·, ·)
  if inputs in expected ranges
    execute randomly one of
    the alternative versions
  else
    execute original version
```

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Transformations:

- **Reductions**: Randomly skip some of the inputs
- Extrapolate the result
- Value of each inputs computed only when required

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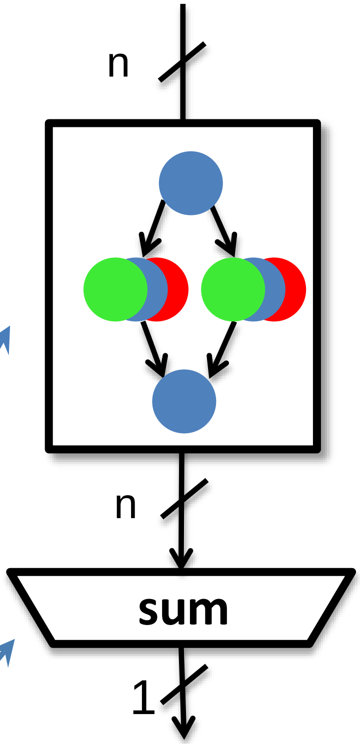

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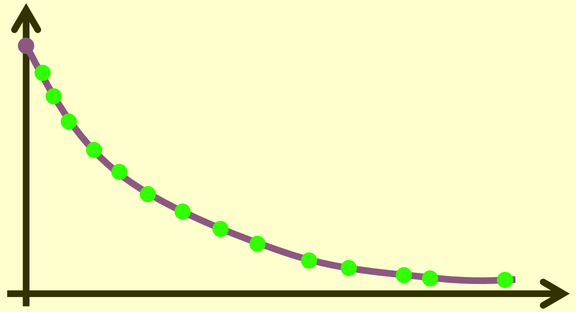
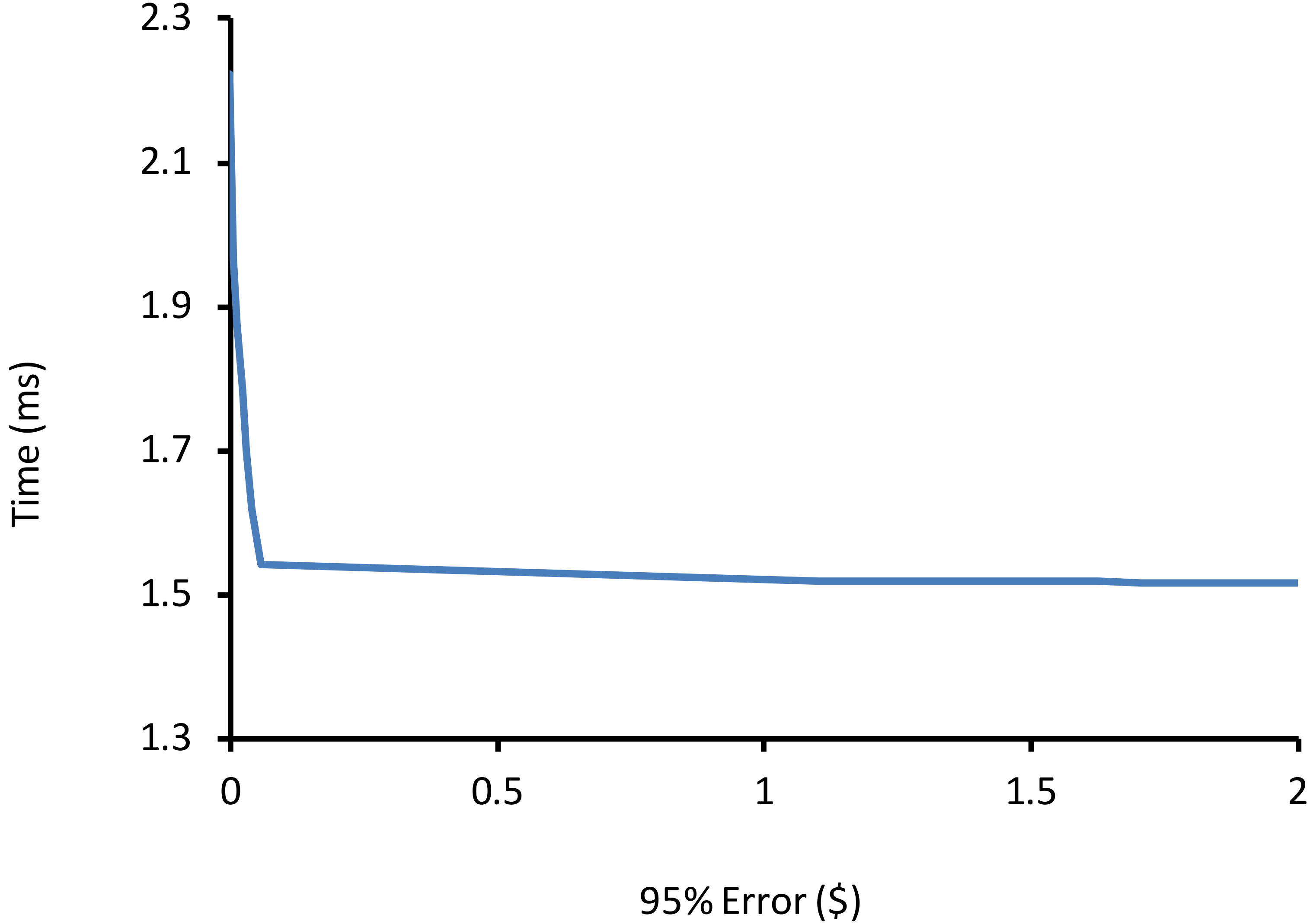
Result:

- Tradeoff curve of the whole program

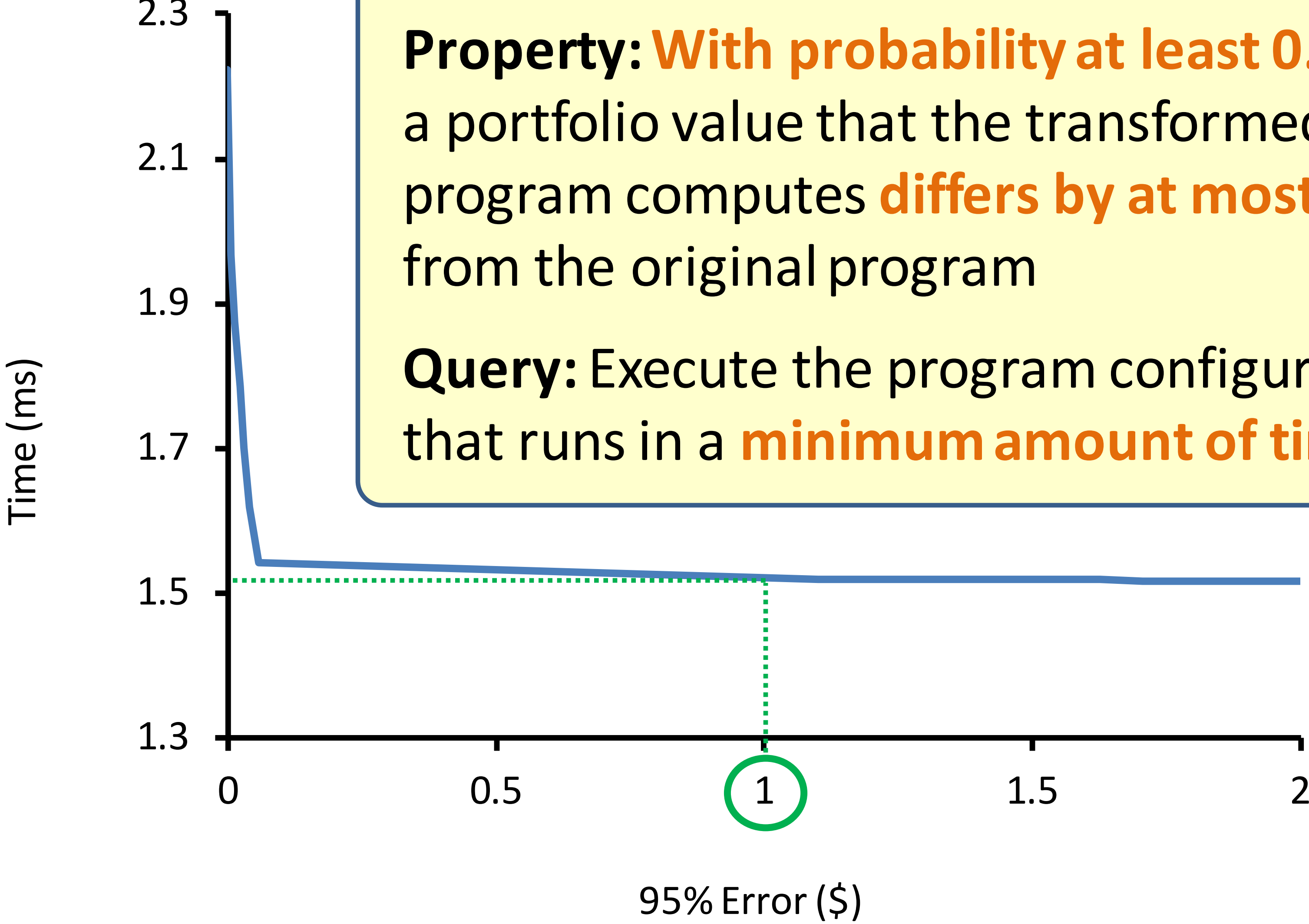


- Randomized program that delivers tradeoffs

Blackscholes: Tradeoff Curve



Blackscholes: Tradeoff Curve



Property: **With probability at least 0.95** a portfolio value that the transformed program computes **differs by at most $1** from the original program

Query: Execute the program configuration that runs in a **minimum amount of time.**

Challenge: Reasoning about Uncertainty

- Expressions for error emergence and propagation
  - Probabilistic analysis
- Influences form of computations we can analyze, tightness of bounds, optimality of the search for transformed programs
- Core algorithm: our POPL '12 paper

Also Check: Michael Carbin's Reasoning about Relaxed Programs Talk (Friday session)

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