Software Engineering Seminar

Atune-IL: An Instrumentation Language for Auto-Tuning Parallel Applications

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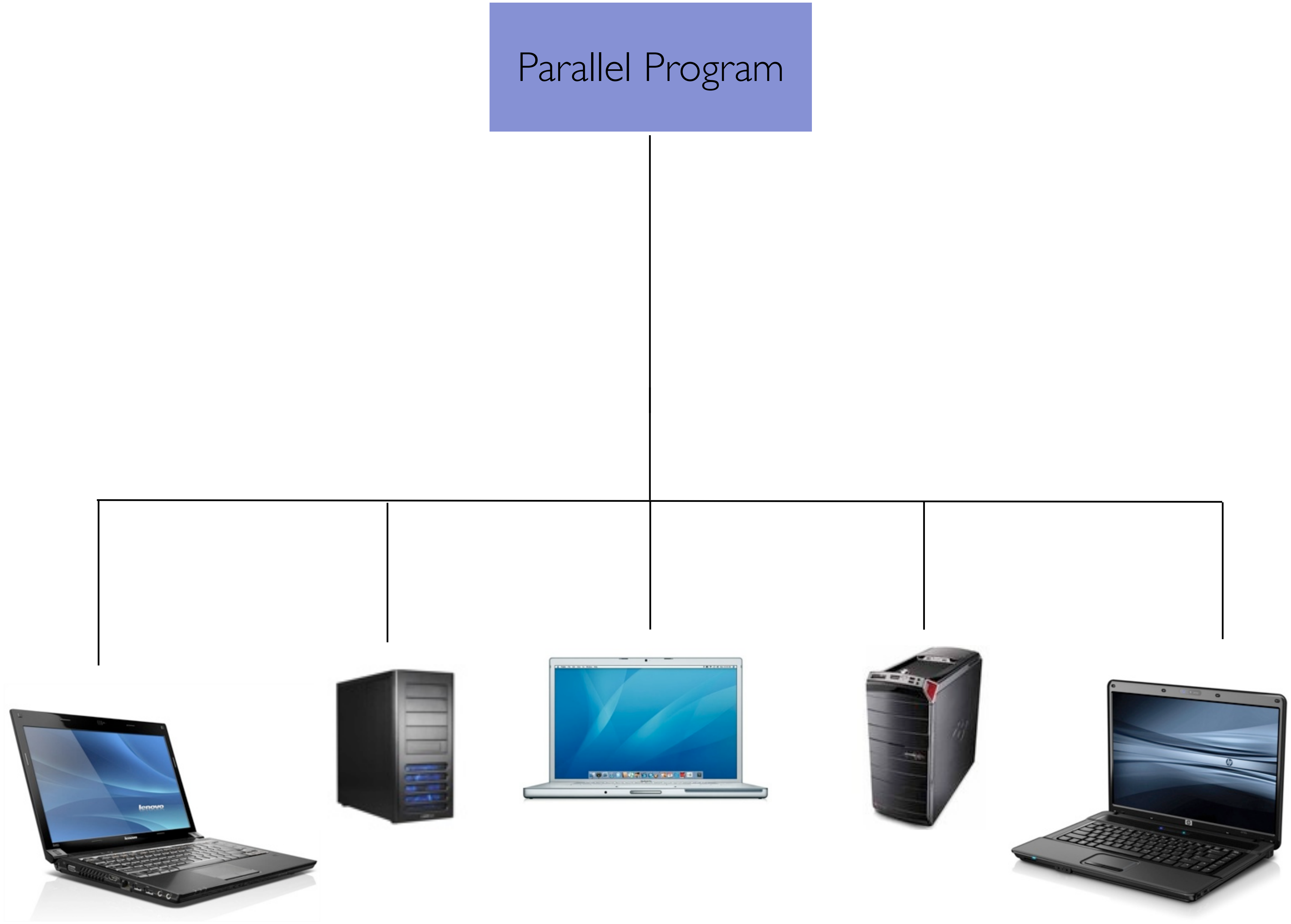
University of Karlsruhe
2009

Michael Berli, December 14th 2011

Motivation



Parallel Program

http://www.teknovadi.com/lenovo-laptop/lenovo-ideapad-b560/ http://lian-li.com/v2/tw/product/upload/image/pc-60fn/pc-60fn-26.jpg http://www.netzwelt.de/news/74776_3-apple-intel-produktuebersicht-erstes-fazit.html http://www.shoppydoo.co.uk/prices-desktop-packard_bell_ipower.html http://stodolatest.pl/produkt/HP_6735s_KU221EA/opinie/0/0/1

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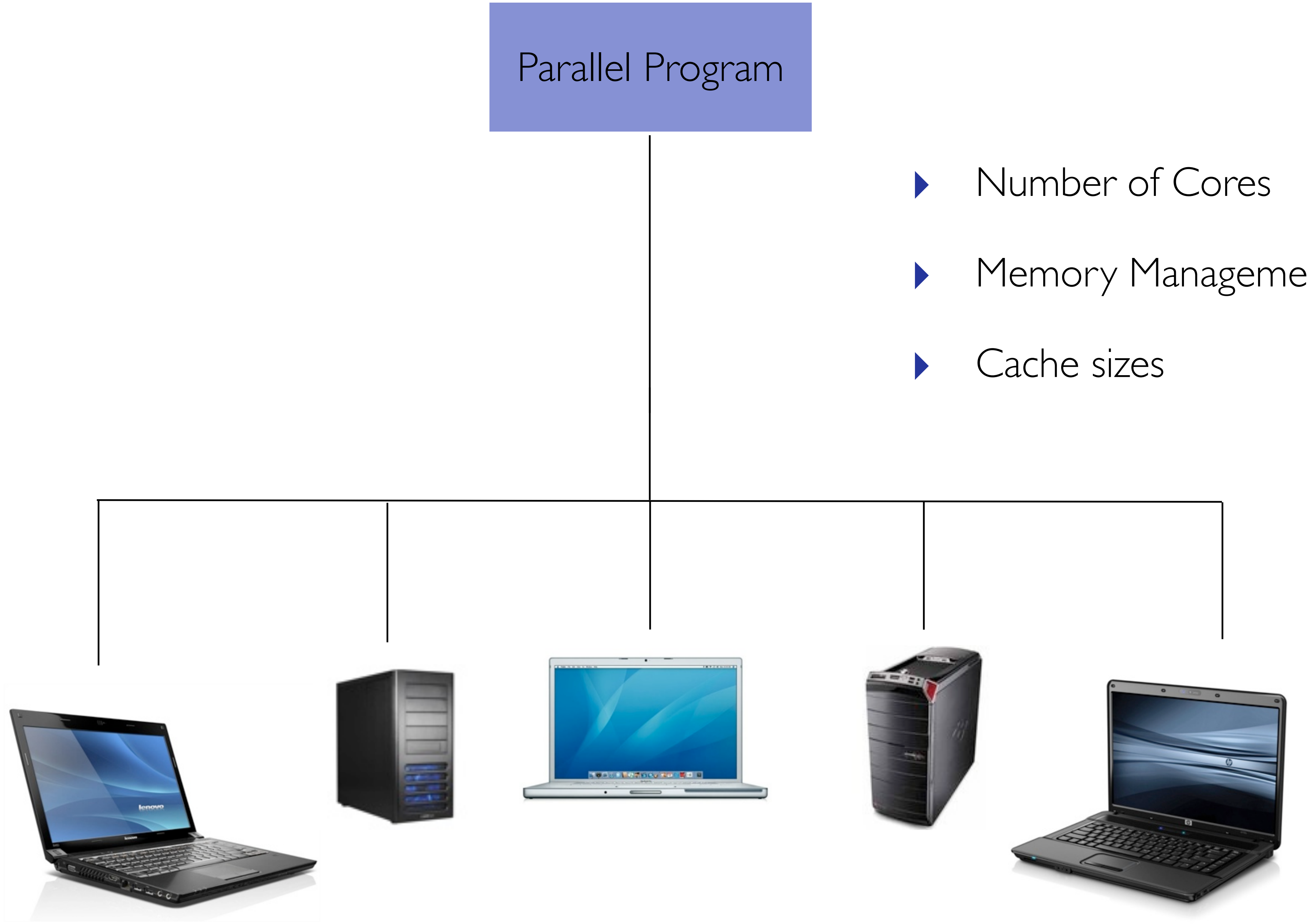

- Number of Cores
- Memory Management
- Cache sizes

http://www.teknovadi.com/lenovo-laptop/lenovo-ideapad-b560/ http://lian-li.com/v2/tw/product/upload/image/pc-60fn/pc-60fn-26.jpg http://www.netzwelt.de/news/74776_3-apple-intel-produktuebersicht-erstes-fazit.html http://www.shoppydoo.co.uk/prices-desktop-packard_bell_ipower.html http://stodolatest.pl/produkt/HP_6735s_KU221EA/opinie/0/0/1

Motivation

Parallel Program

- Number of Cores
- Memory Management
- Cache sizes

gain optimal performance

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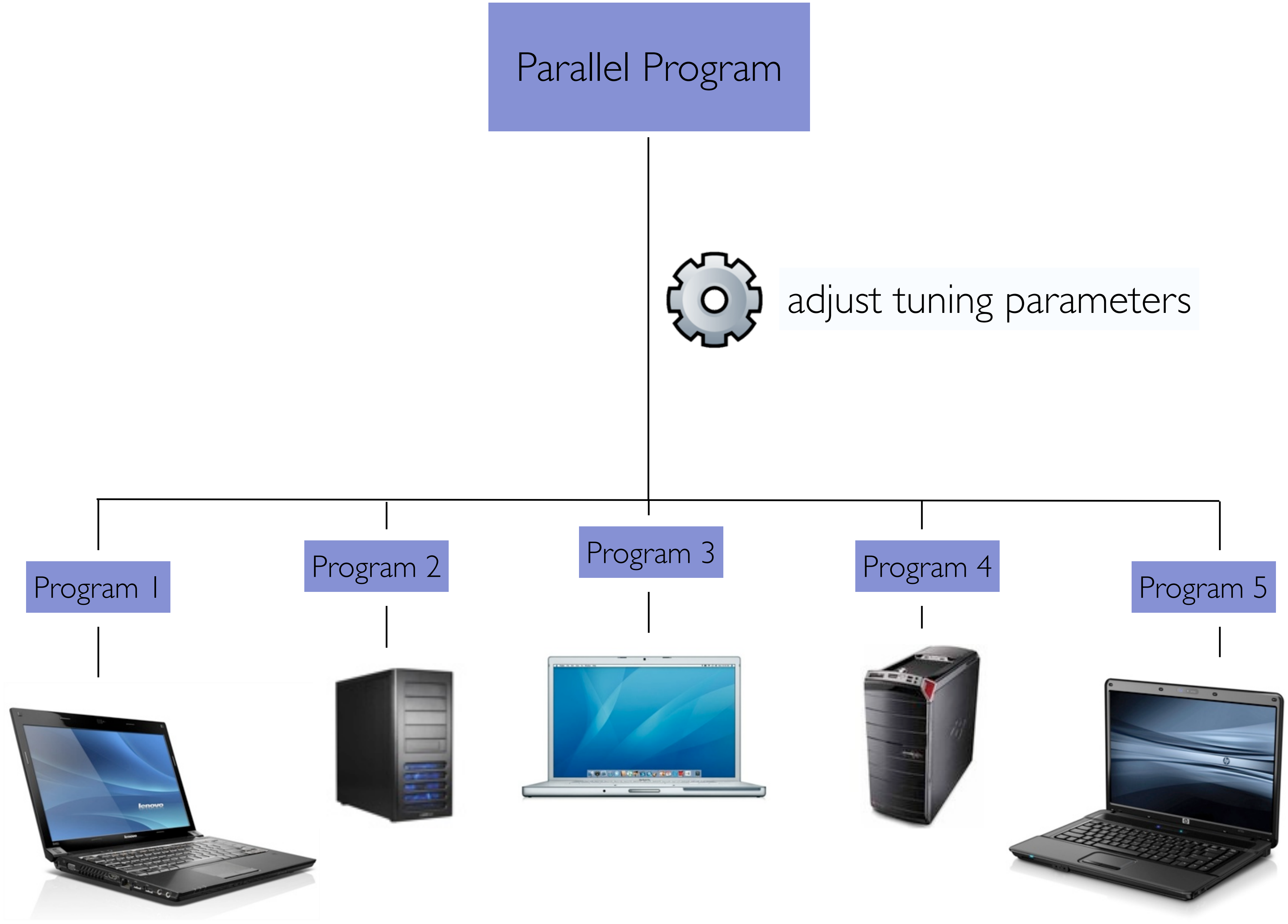

Parallel Program

adjust tuning parameters

Program 1

Program 2

Program 3

Program 4

Program 5

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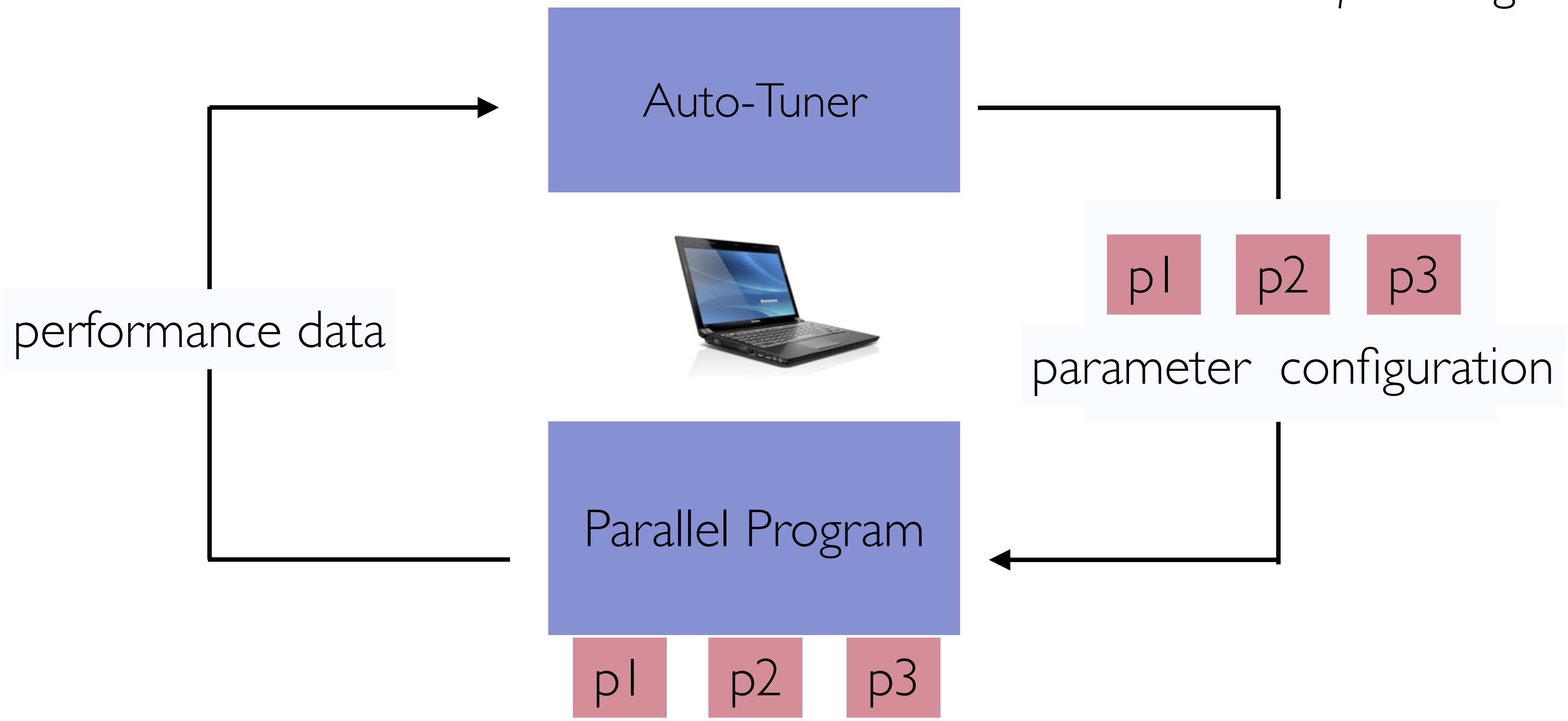
Automatic Performance Tuning

- Auto-Tuner: Generate several program variants automatically
  - on a specific architecture
  - find an optimal tuning parameter configuration

p1:	2, 4, 6, 8
p2:	„static“, „dynamic“
p3:	algo1, algo2



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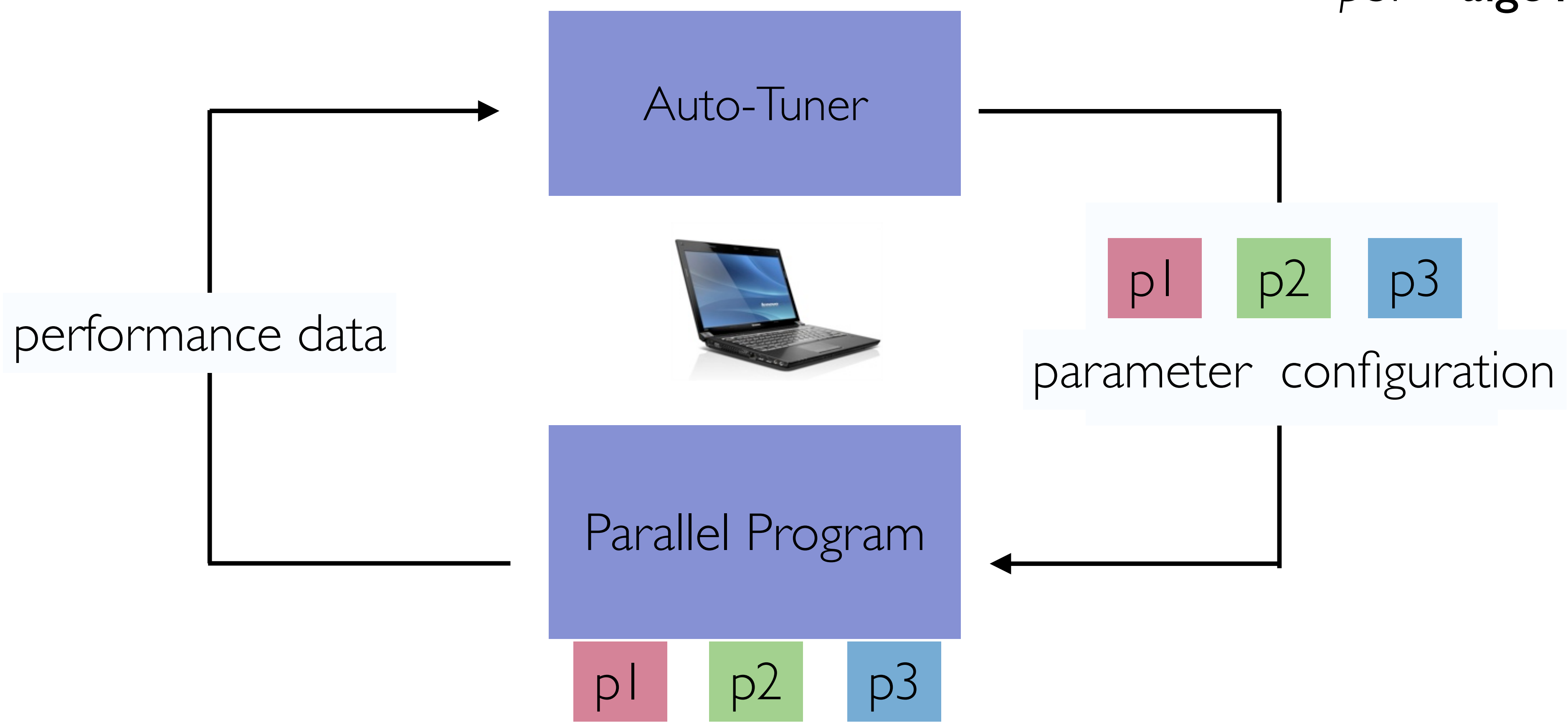

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Automatic Performance Tuning

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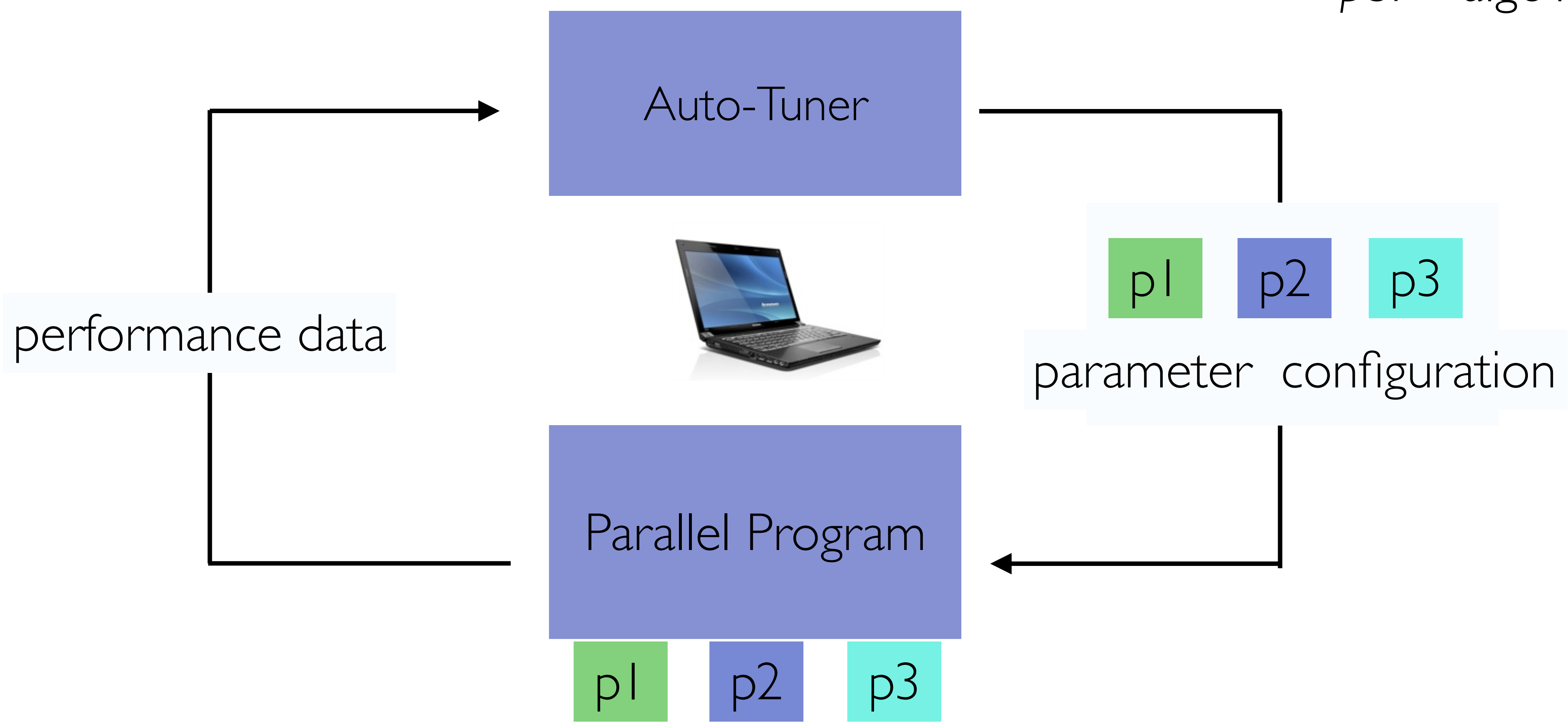

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Automatic Performance Tuning

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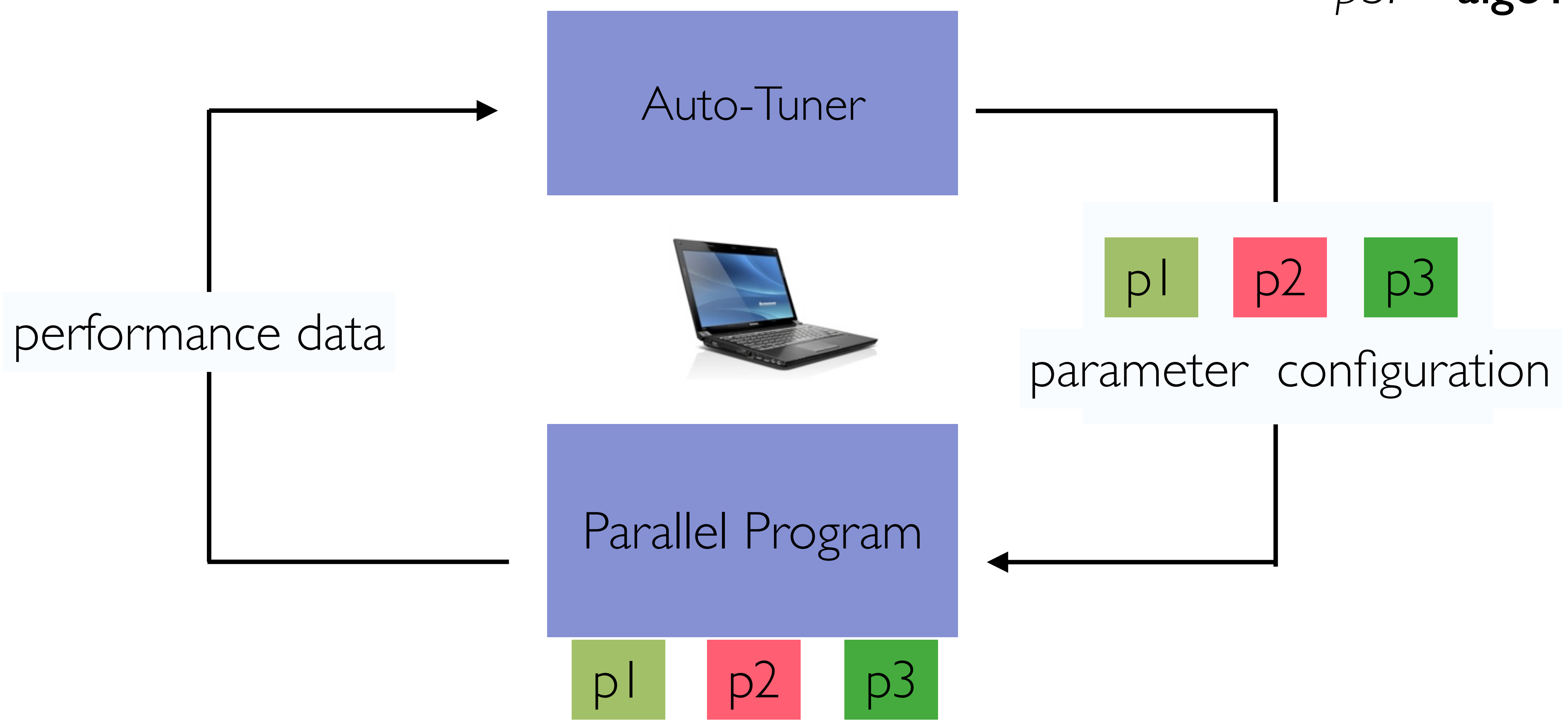

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Automatic Performance Tuning

- Huge search space
  - cross product of parameter domains

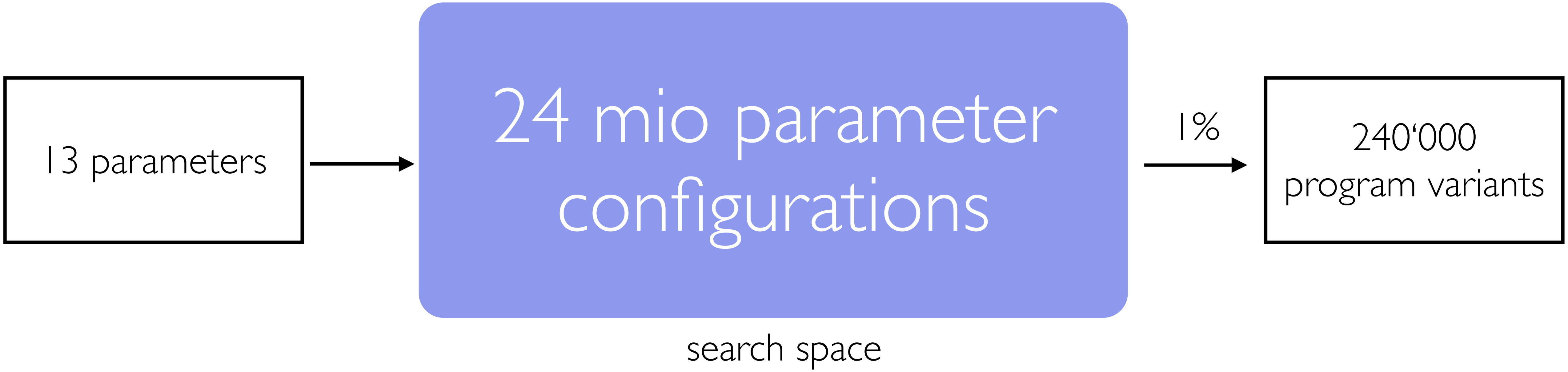
$$S = dom(p_1) \times ... \times dom(p_n)$$

p1:	2, 4, 6, 8	dom(p1) = 4
p2:	static, dynamic	dom(p2) = 2
p3:	algo1, algo2	dom(p3) = 2

Automatic Performance Tuning

- **Huge search space**
  - cross product of parameter domains

$$S = dom(p_1) \times ... \times dom(p_n)$$

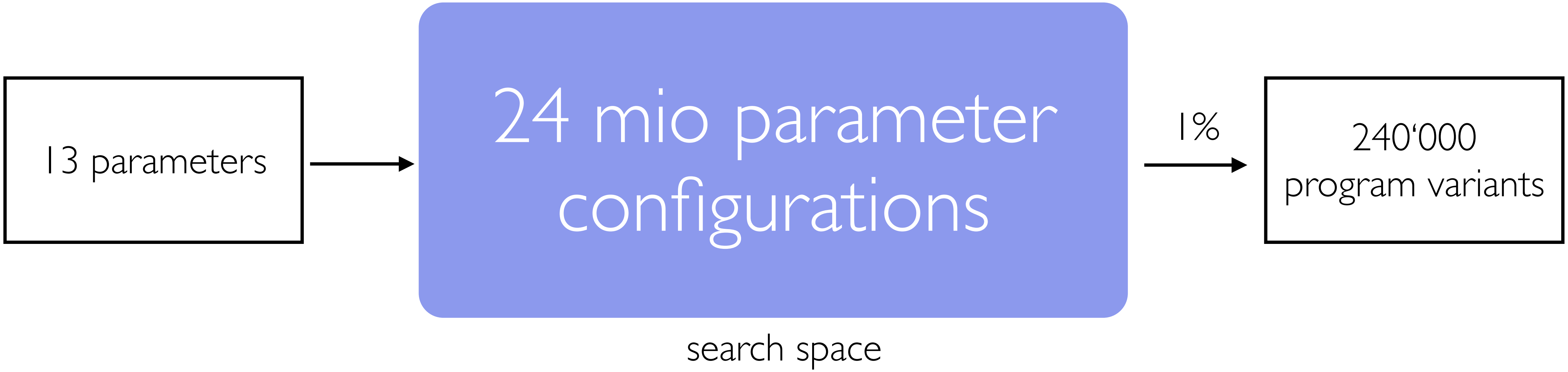


Automatic Performance Tuning

- **Huge search space**
  - cross product of parameter domains

$$S = dom(p_1) \times \ldots \times dom(p_n)$$

need to prune the search space !



13 parameters

24 mio parameter configurations

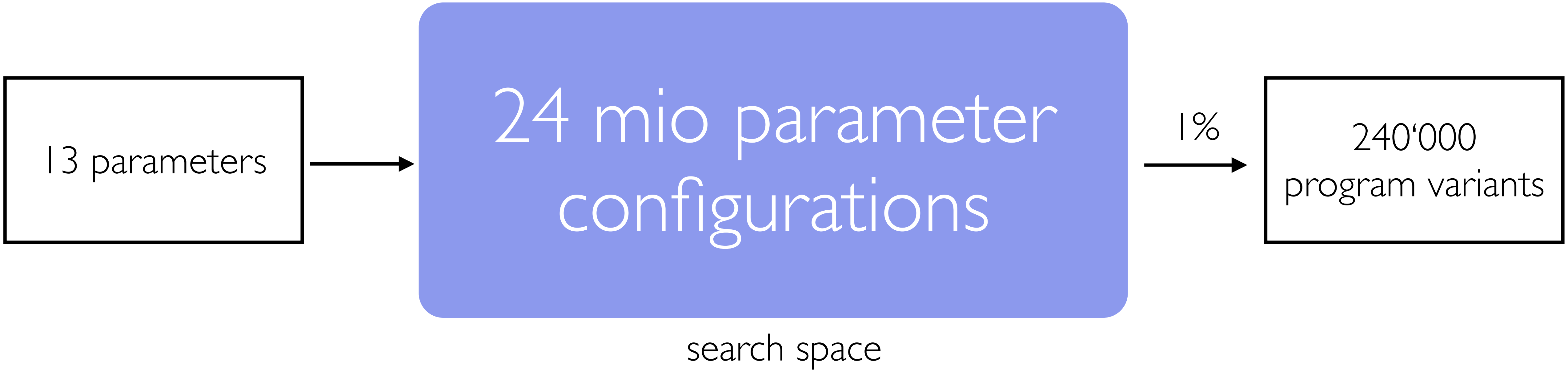
search space

1%

240‘000 program variants

Automatic Performance Tuning

- Three ways to prune the search space
  - try & fail
  - make use of heuristics / previous tuning iterations
  - use the developers knowledge



13 parameters

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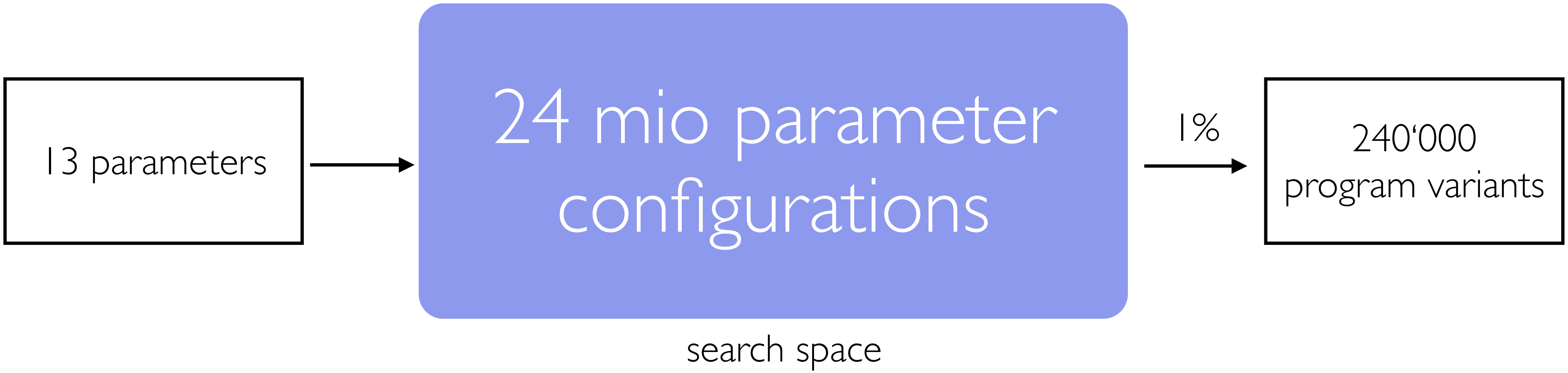
search space

1%

240‘000 program variants

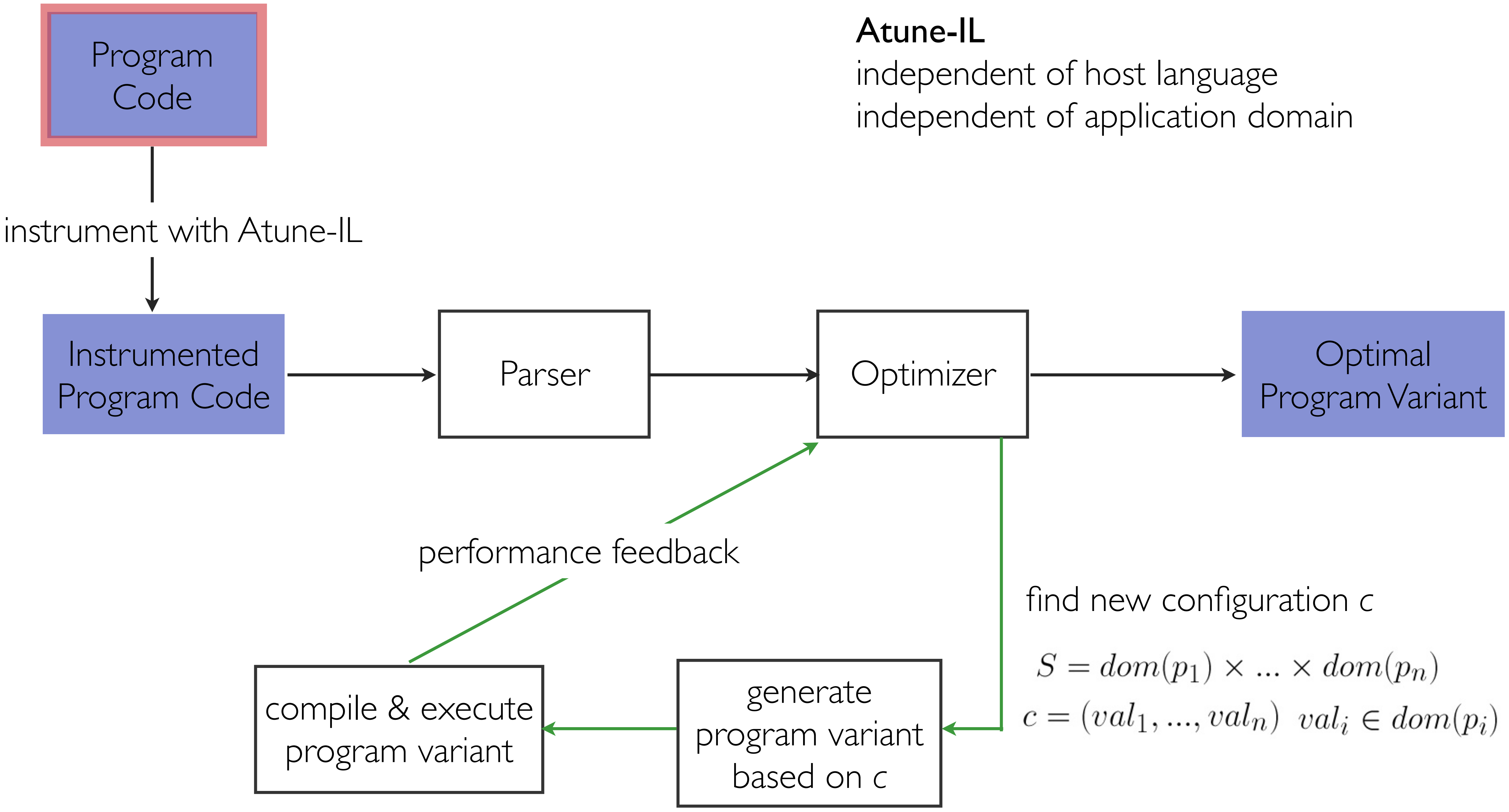
Automatic Performance Tuning

- Three ways to prune the search space
  - try & fail
  - make use of heuristics / previous tuning iterations
  - ✓ use the developers knowledge
    - Atune-IL: annotate tuning parameters, independent sections, monitoring probes...



Atune‘s tuning cycle

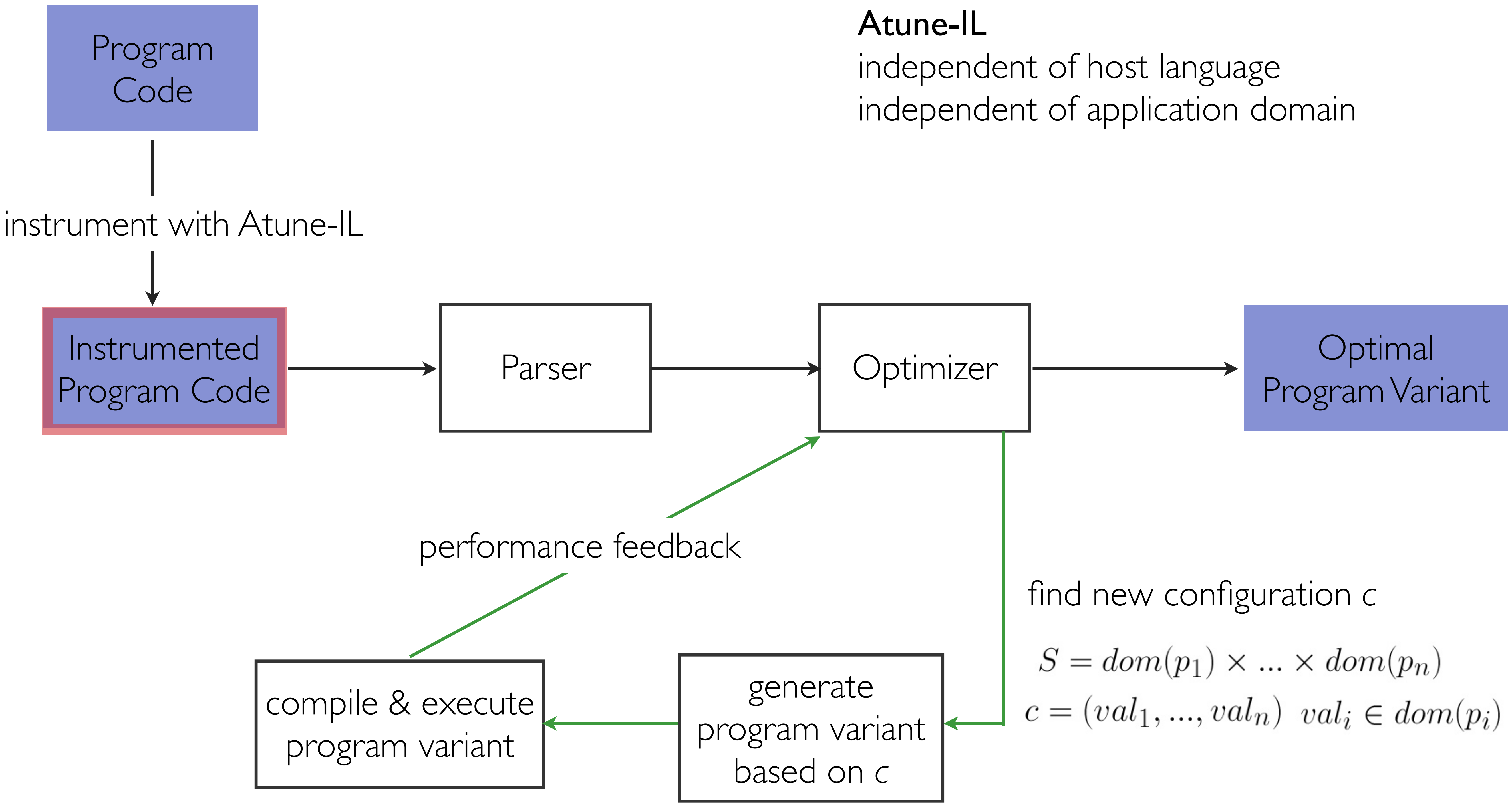
Atune-IL
independent of host language
independent of application domain



$$S = dom(p_1) \times ... \times dom(p_n)$$

$$c = (val_1, ..., val_n) \;\; val_i \in dom(p_i)$$

Atune‘s tuning cycle



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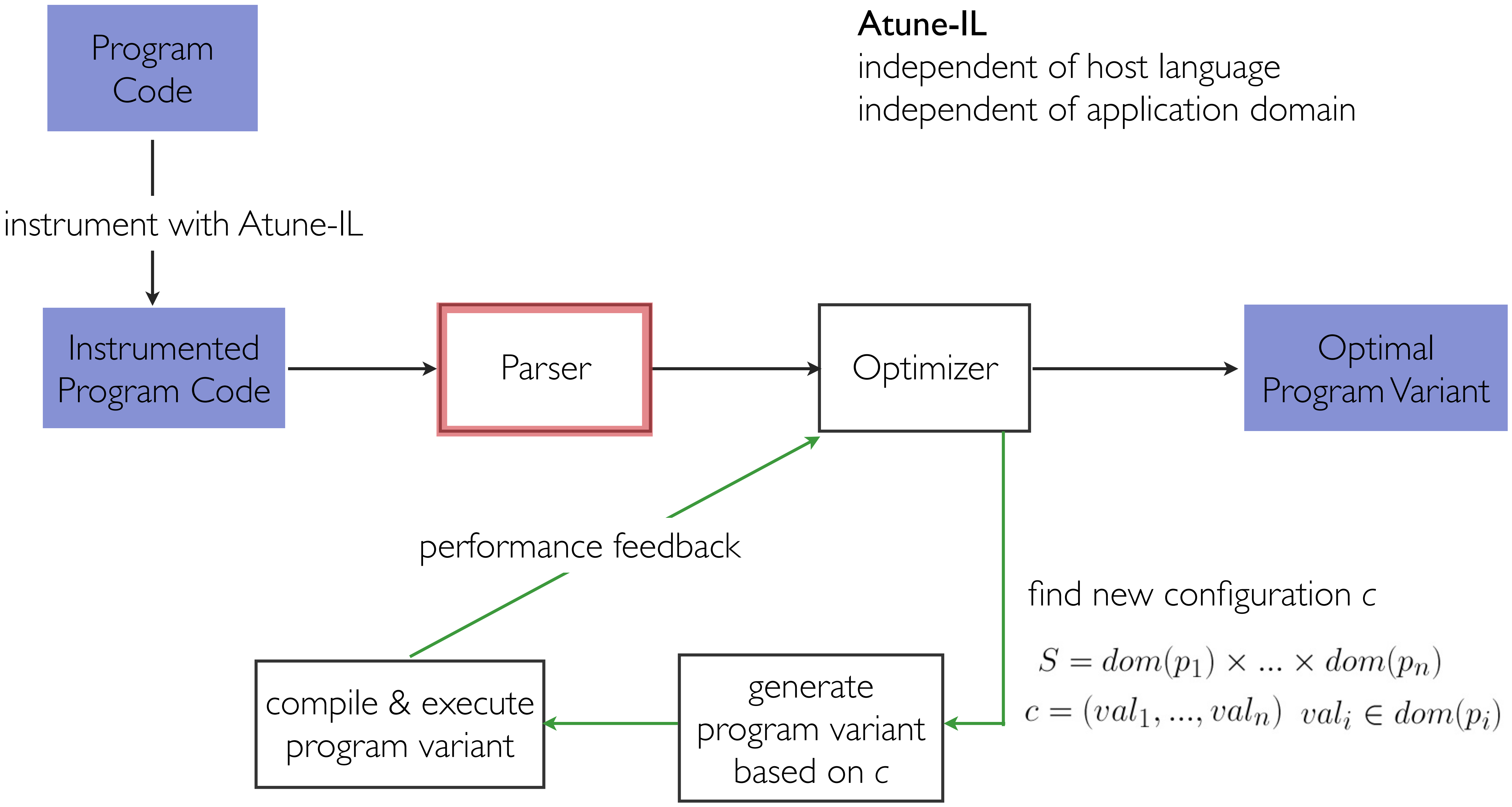

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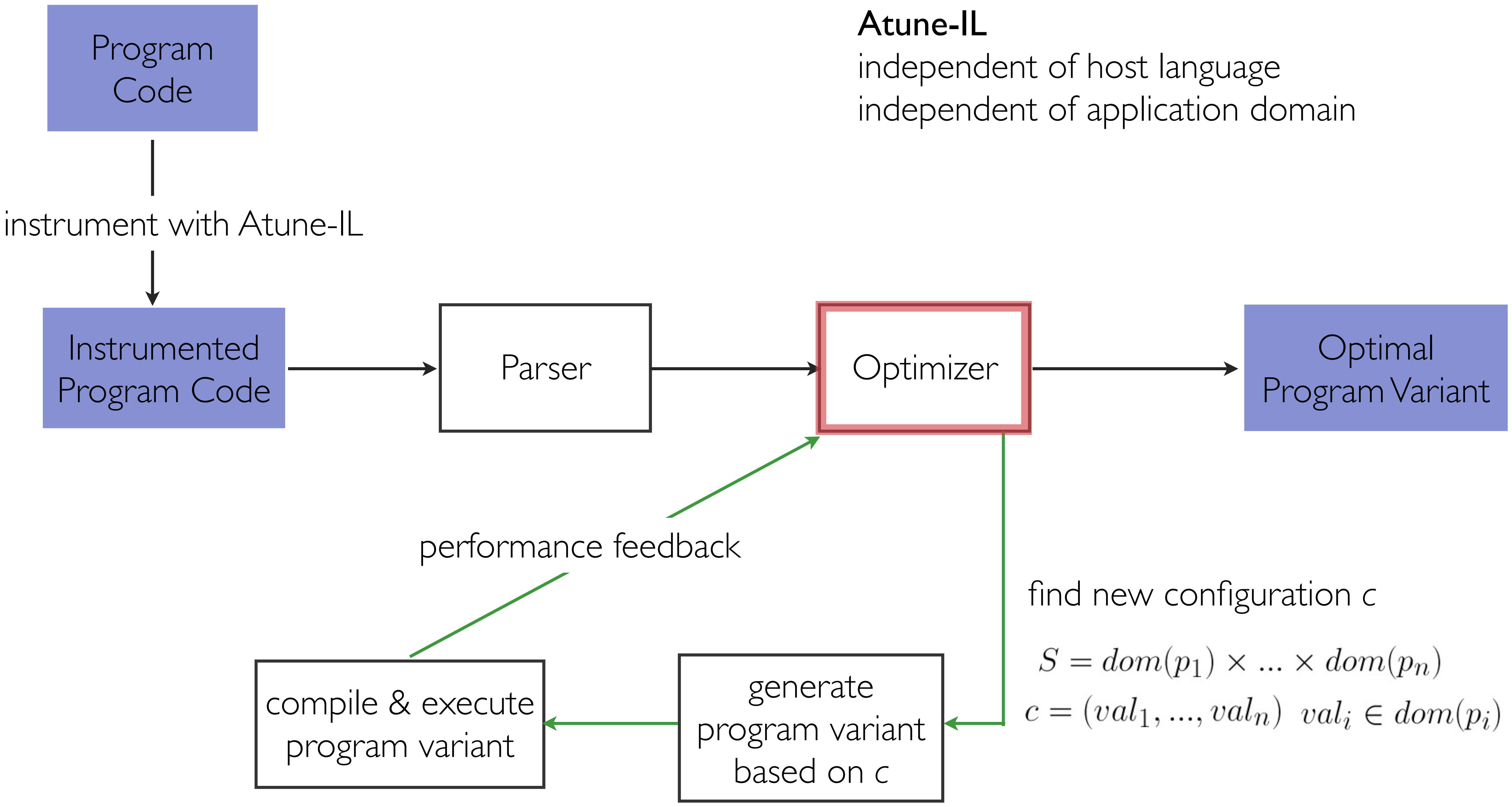

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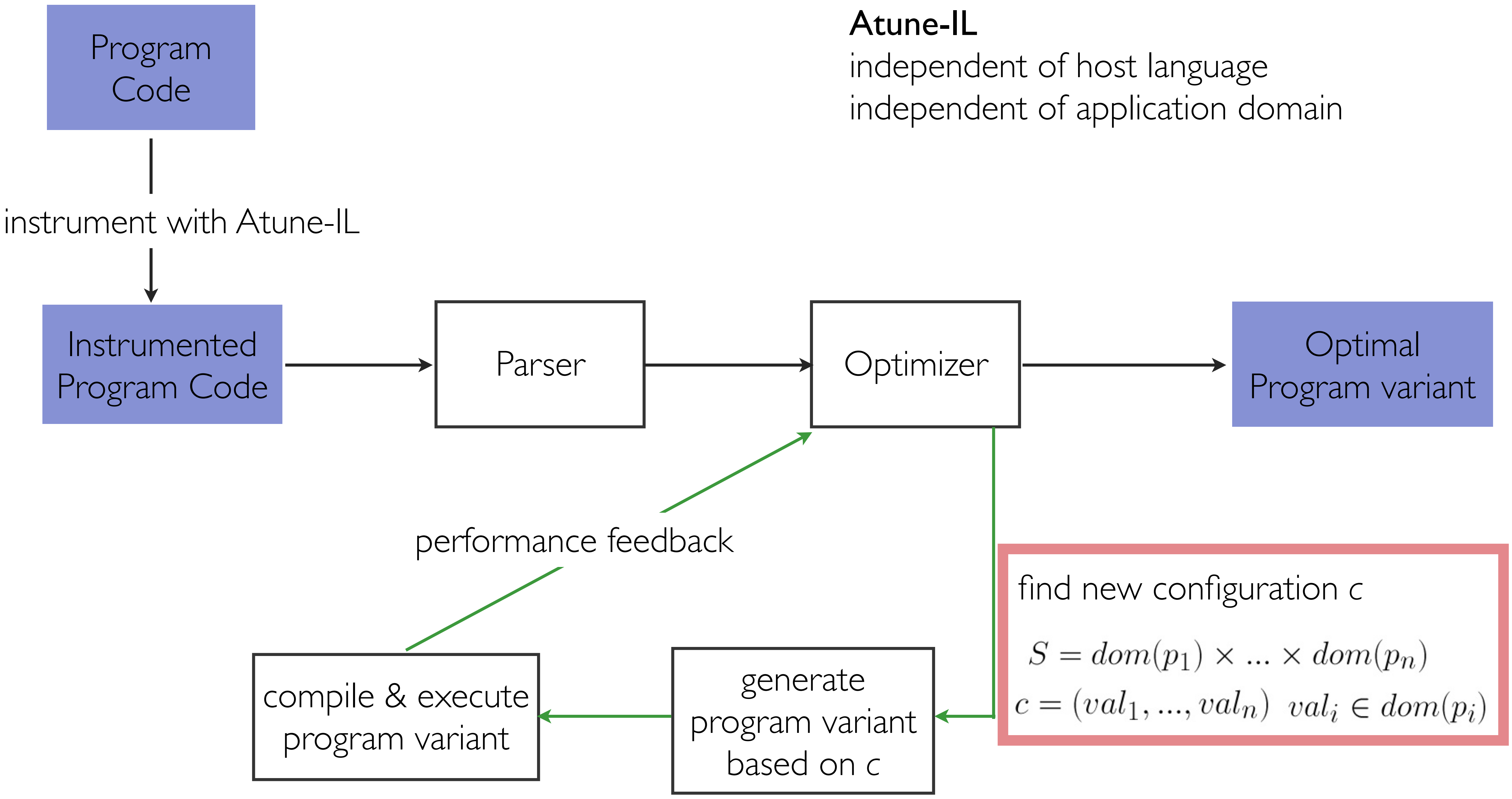

Program Code

instrument with Atune-IL

Instrumented Program Code

Parser

Optimizer

Optimal Program variant

performance feedback

compile & execute program variant

generate program variant based on c

find new configuration c

$$S = dom(p_1) \times ... \times dom(p_n)$$

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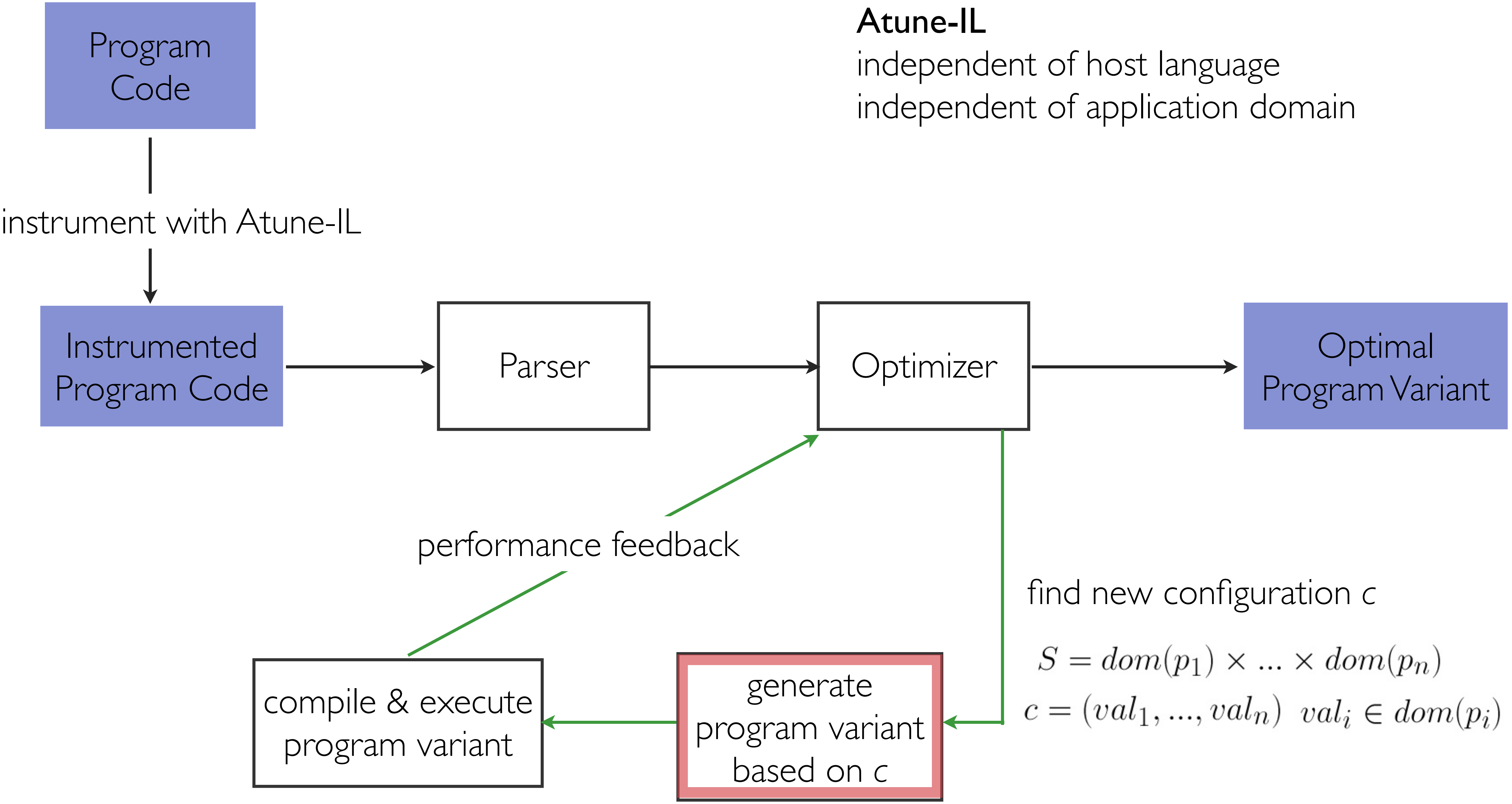

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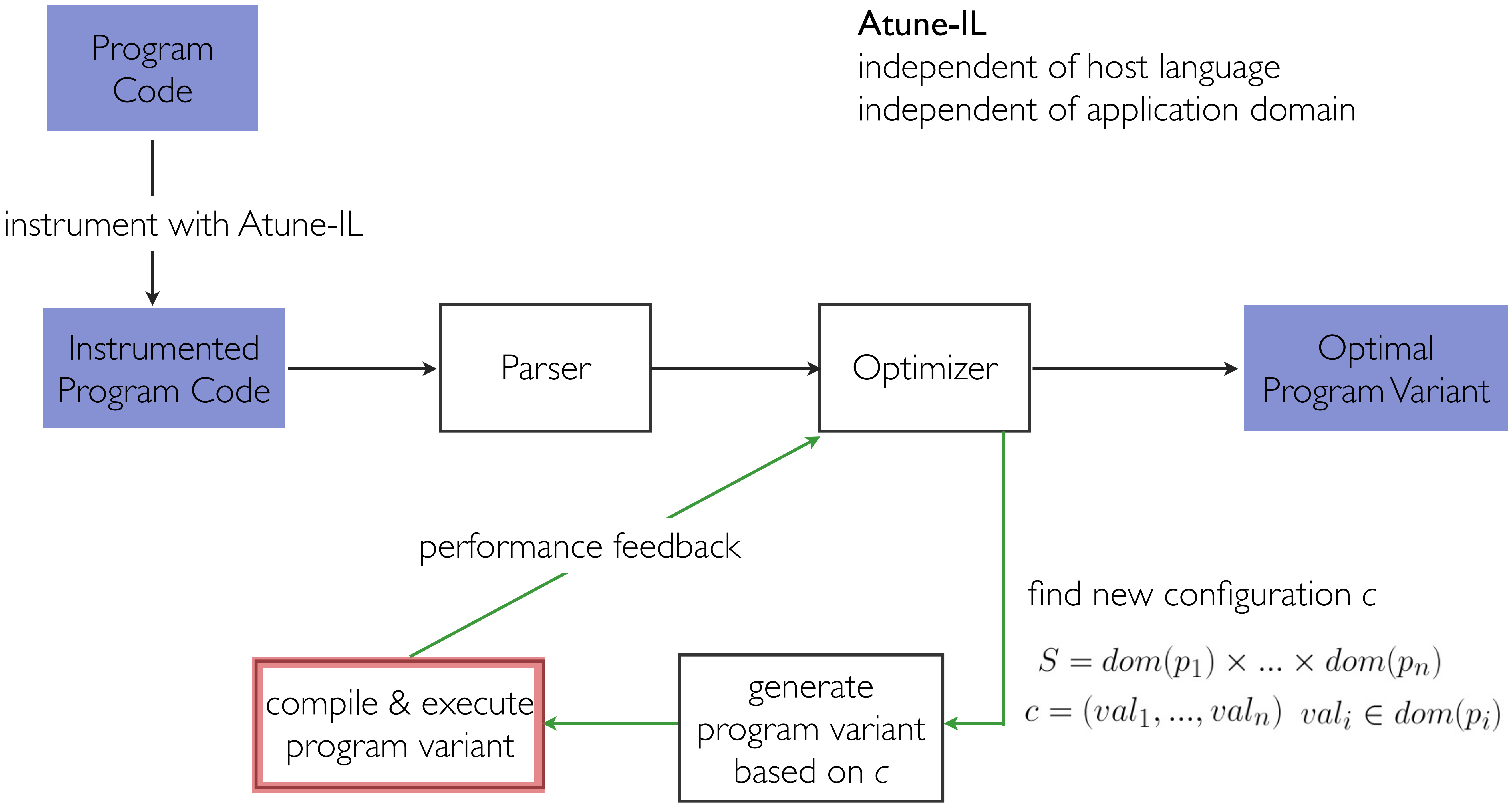

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Optimal Program Variant

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generate program variant based on c

compile & execute program variant

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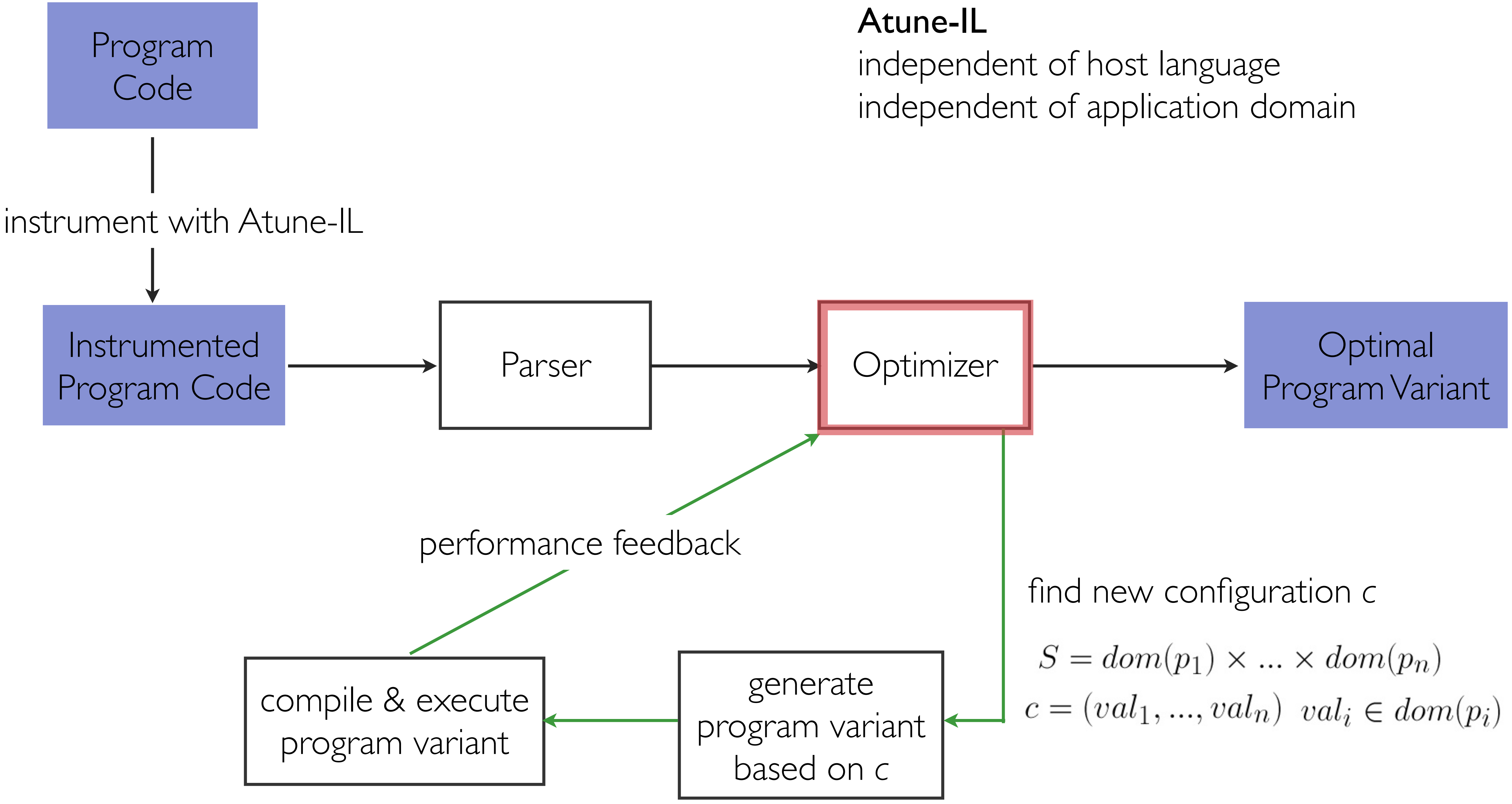

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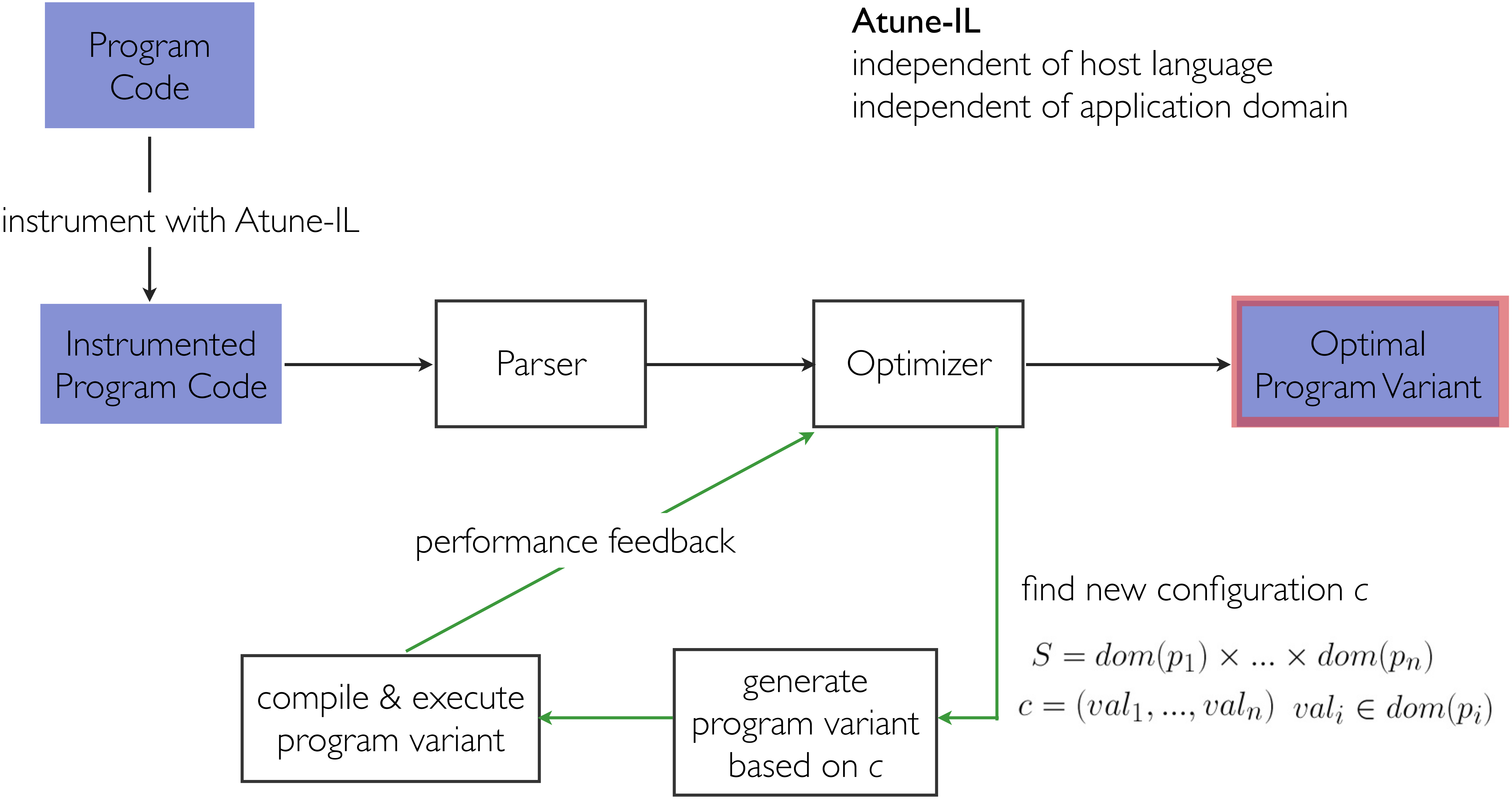

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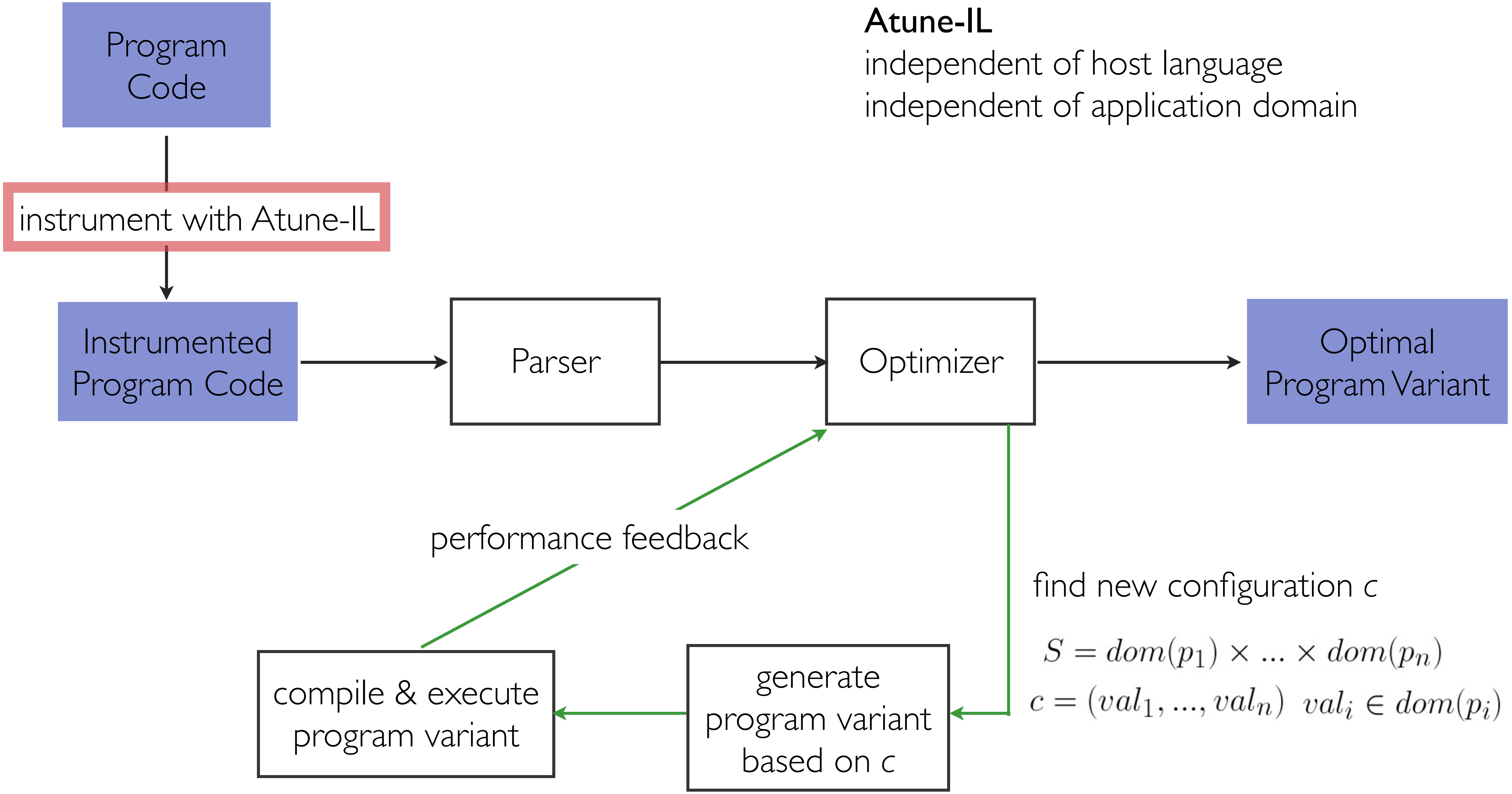

Program Code

instrument with Atune-IL

Instrumented Program Code

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Optimizer

Optimal Program Variant

find new configuration c

$$S = dom(p_1) \times ... \times dom(p_n)$$

$$c = (val_1, ..., val_n) \quad val_i \in dom(p_i)$$

generate program variant based on c

compile & execute program variant

performance feedback

Numeric Parameters

- SETVAR keyword

```
public void SETVAR_Example()
{
  int numThreads = 2;



  for (int i=1; i <=numThreads; i++){
    Thread.Create(StartCalculation);
  }
  WaitAll();
}
```

Numeric Parameters

- SETVAR keyword

```
public void SETVAR_Example()
{
  int numThreads = 2;
  #pragma atune SETVAR numThreads TYPE int
  VALUES 2-16 STEP 2

  for (int i=1; i <=numThreads; i++){
    Thread.Create(StartCalculation);
  }
  WaitAll();
}
```

2, 4, ..., 16 Threads

Architectural Parameters

- SETVAR keyword

```
public void SETVAR_Example2()
{
  SortAlgorithm sortAlgo = new ParallelMergeSort();

  #pragma atune SETVAR sortAlgo TYPE generic VALUES
  „new QuickSort()“, „new ParallelMergeSort()“

  if (sortAlgo != null)
    sortAlgo.run();
}
```

Parameter Dependencies

- DEPENDS keyword

```
public void DEPENDS_Example()
{
  SortAlgorithm sortAlgo = new ParallelMergeSort();

  #pragma atune SETVAR sortAlgo TYPE generic VALUES
  „new QuickSort()“, „new ParallelMergeSort()“

    int depth = 2;

    #pragma atune SETVAR depth TYPE int VALUES 2-8

  if (sortAlgo != null)
    sortAlgo.run(depth);
}
```

14 combinations

Parameter Dependencies

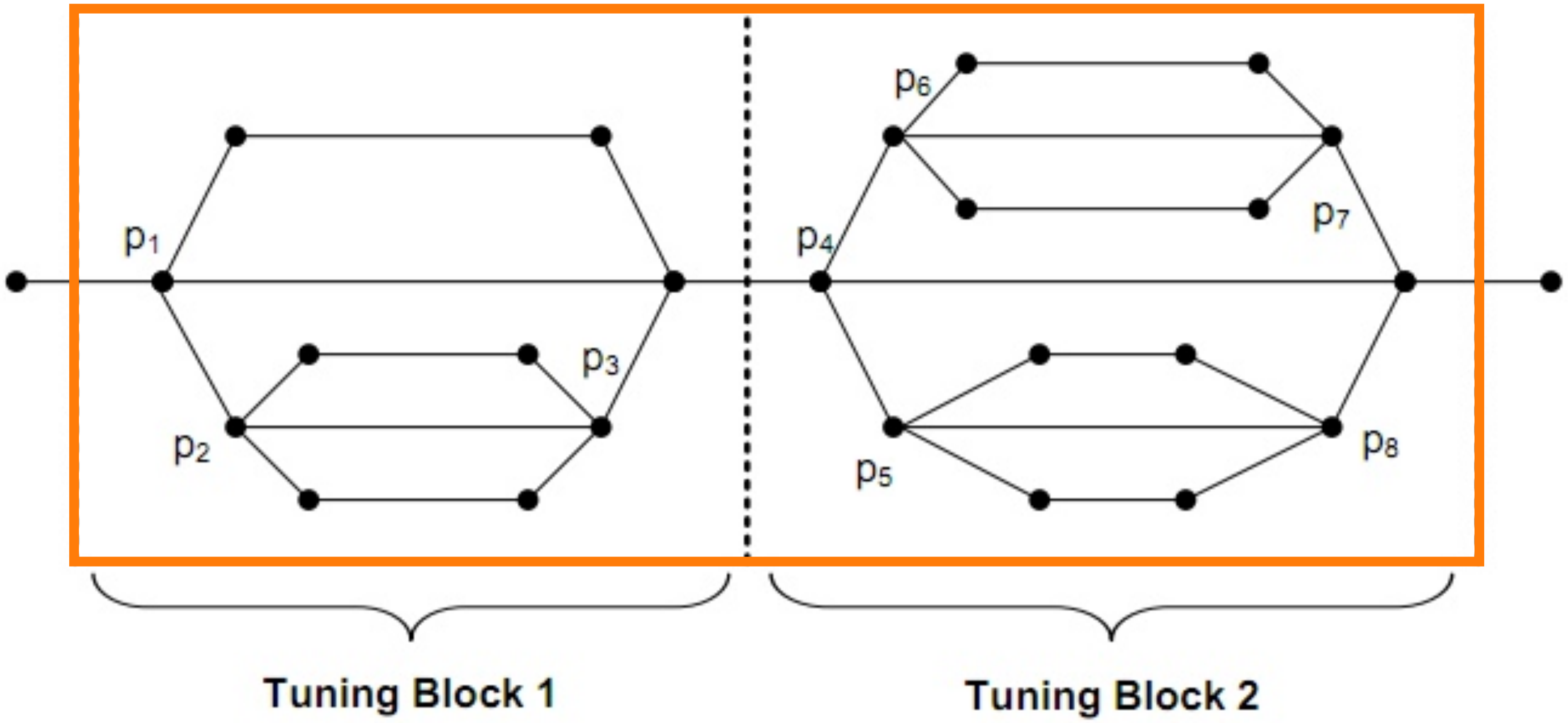
- DEPENDS keyword

```
public void DEPENDS_Example()
{
  SortAlgorithm sortAlgo = new ParallelMergeSort();

  #pragma atune SETVAR sortAlgo TYPE generic VALUES
  „new QuickSort()“, „new ParallelMergeSort()“

    int depth = 2;

    #pragma atune SETVAR depth TYPE int VALUES 2-8
    DEPENDS sortAlgo VALUES “new ParallelMergeSort()“

  if (sortAlgo != null)
    sortAlgo.run(depth);
}
```

8 combinations
instead of 14!

Tuning Blocks

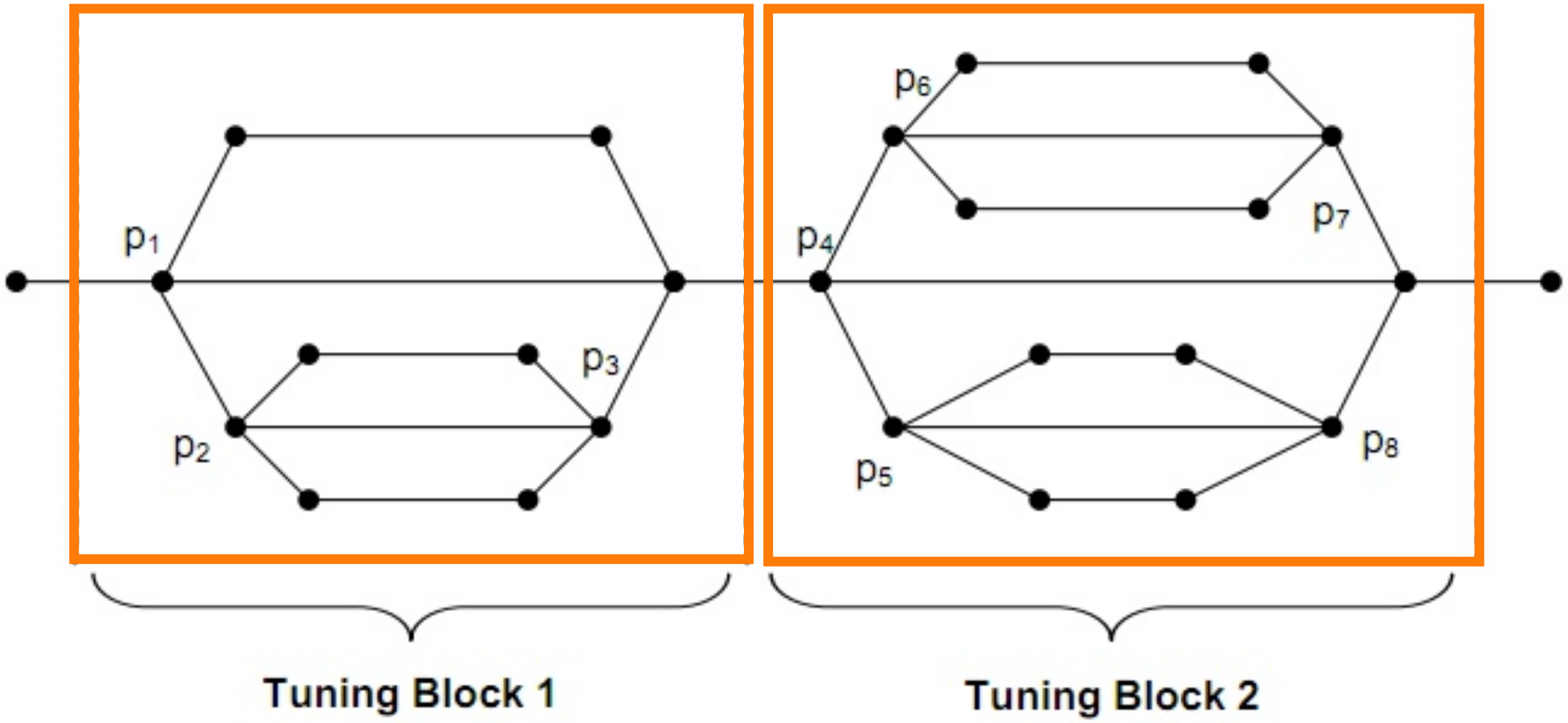
- Define independent sections
  - Tuning-Approach 1: $dom(p_1) \times ... \times dom(p_8)$
  - **Tuning-Approach 2:**
    - Tuning-Block 1: $dom(p_1) \times ... \times dom(p_3)$
    - Tuning-Block 2: $dom(p_4) \times ... \times dom(p_8)$



http://www.ipd.uni-karlsruhe.de/multicore/research/download/ATuneIL-Autotuning.pdf

Tuning Blocks

- Define independent sections
  - Tuning-Approach 1: $dom(p_1) \times ... \times dom(p_8)$
  - Tuning-Approach 2:
    - Tuning-Block 1: $dom(p_1) \times ... \times dom(p_3)$
    - Tuning-Block 2: $dom(p_4) \times ... \times dom(p_8)$



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Tuning Blocks

- STARTBLOCK keyword

```
public void TUNINGBLOCKS_Example()
{
    // other tuning parameters...


     #pragma atune STARTBLOCK parallelSection
    int numThreads = 2;
    #pragma atune SETVAR numThreads
    TYPE int VALUES 2-16 STEP 2

    for (int i=1; i <=numThreads; i++){
      Thread.Create(StartCalculation);
    }
    WaitAll();
     #pragma atune ENDBLOCK

}
```

Nested Tuning Blocks

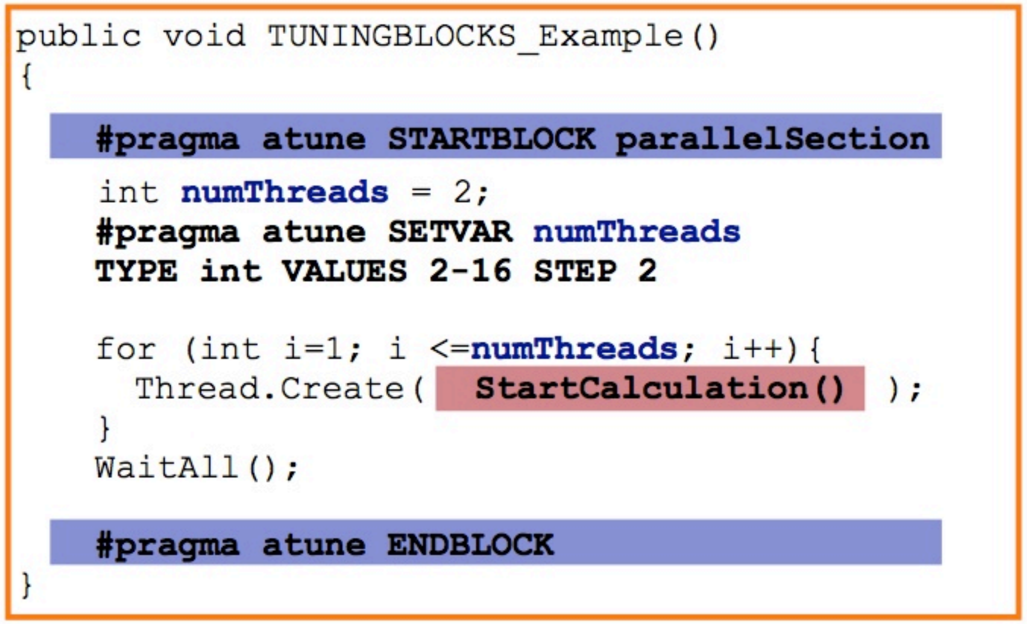
- INSIDE keyword
  - optimization starts with the innermost block
  - combines inner and outer parameters successively

```
public void TUNINGBLOCKS_Example()
{
    #pragma atune STARTBLOCK parallelSection
    int numThreads = 2;
    #pragma atune SETVAR numThreads
    TYPE int VALUES 2-16 STEP 2

    for (int i=1; i <=numThreads; i++){
      Thread.Create(  StartCalculation()  );
    }
    WaitAll();

    #pragma atune ENDBLOCK
}
```

Nested Tuning Blocks

- INSIDE keyword
  - optimization starts with the innermost block
  - combines inner and outer parameteters successively

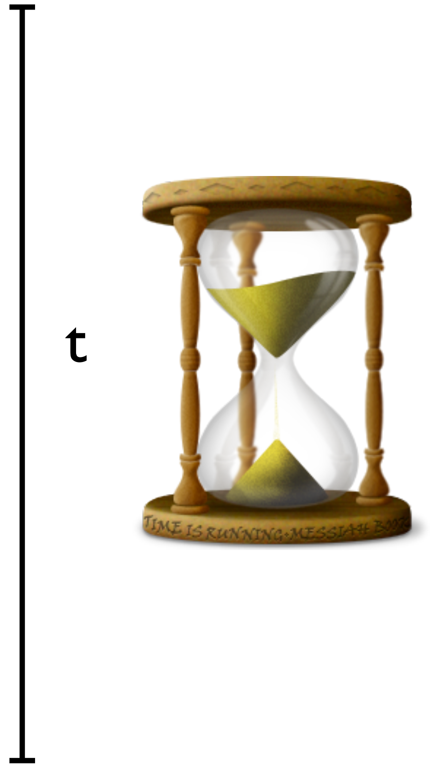
```
public void  StartCalculation()
{
    #pragma atune STARTBLOCK
    nestedSection INSIDE parallelSection

    /* calculation with own tuning
    parameters */

    #pragma atune ENDBLOCK
}
```



```
public void TUNINGBLOCKS_Example()
{
   #pragma atune STARTBLOCK parallelSection
   int numThreads = 2;
   #pragma atune SETVAR numThreads
   TYPE int VALUES 2-16 STEP 2

   for (int i=1; i <=numThreads; i++){
     Thread.Create( StartCalculation() );
   }
   WaitAll();

   #pragma atune ENDBLOCK
}
```

Monitoring Probes

```
public void TUNINGBLOCKS_Example()
{
     #pragma atune STARTBLOCK parallelSection
      #pragma atune GAUGE execTime
    int numThreads = 2;
    #pragma atune SETVAR numThreads
    TYPE int VALUES 2-16 STEP 2

    for (int i=1; i <=numThreads; i++){
      Thread.Create(StartCalculation());
    }
    WaitAll();
      #pragma atune GAUGE execTime
     #pragma atune ENDBLOCK
}
```



http://www.iconfinder.com/icondetails/48883/256/

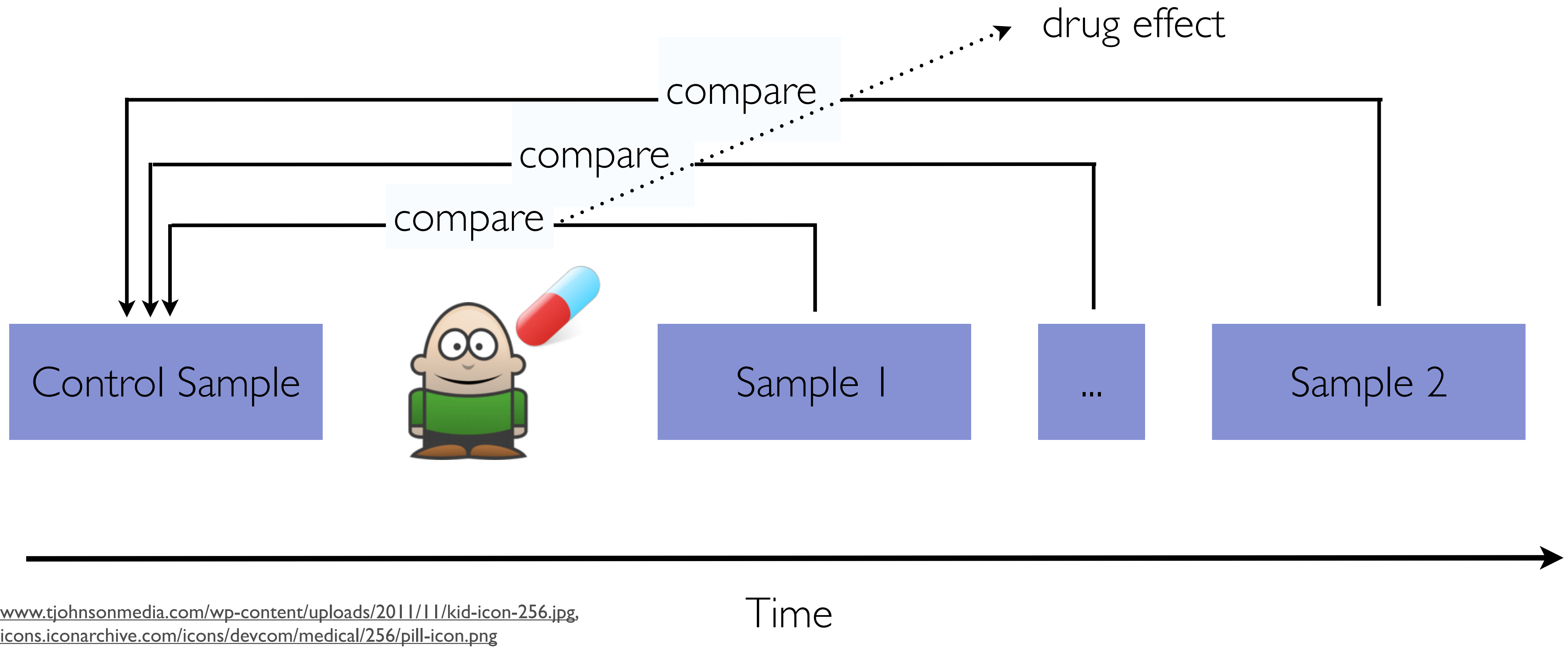
Context

- ✓ Motivation
- ✓ Introduction to Auto-Tuning
- ✓ Atune‘s Tuning Cycle
- ✓ Atune-IL
- ▸ Case Study
  - ▸ Results
- ▸ Pros & Cons

http://images.productwiki.com/upload/images/safari_iphone_app-400-400.jpg

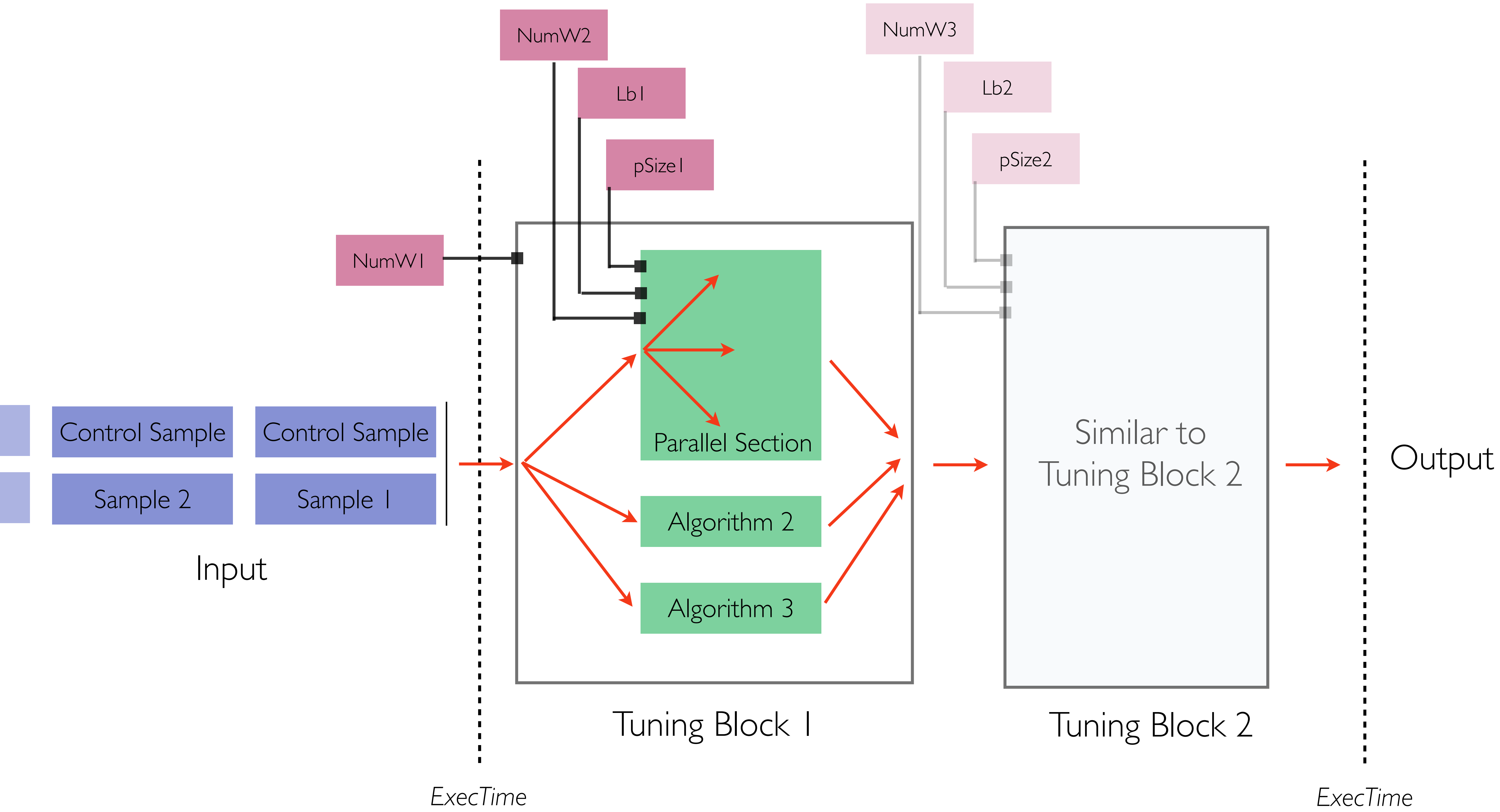
Case Study

- MetaboliteID (Agilent Technologies)
- Identify effects caused by a drug on a very low level
  - by comparing control samples to metabolite samples



http://www.tjohnsonmedia.com/wp-content/uploads/2011/11/kid-icon-256.jpg,
http://icons.iconarchive.com/icons/devcom/medical/256/pill-icon.png

Metabolite ID



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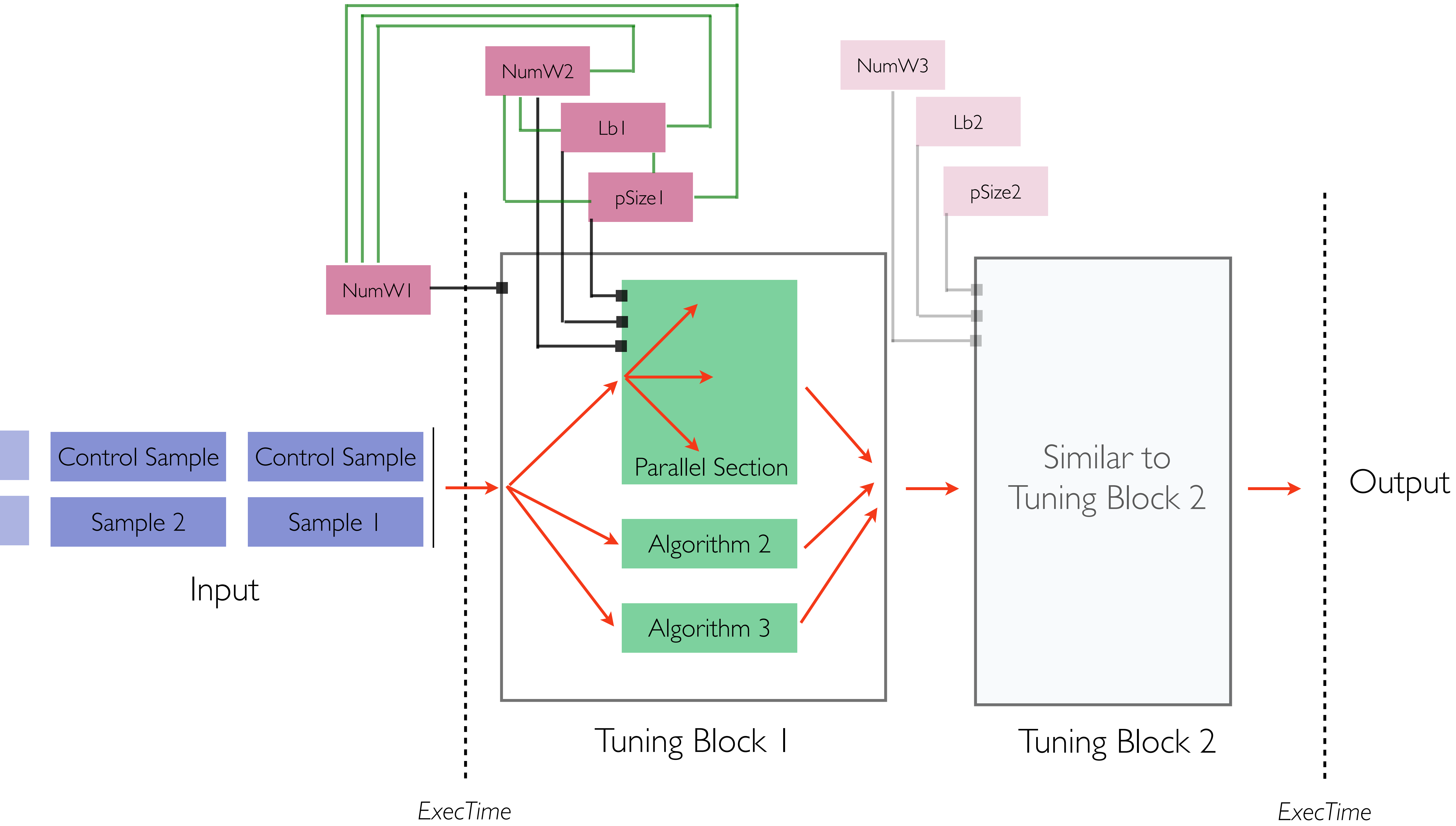

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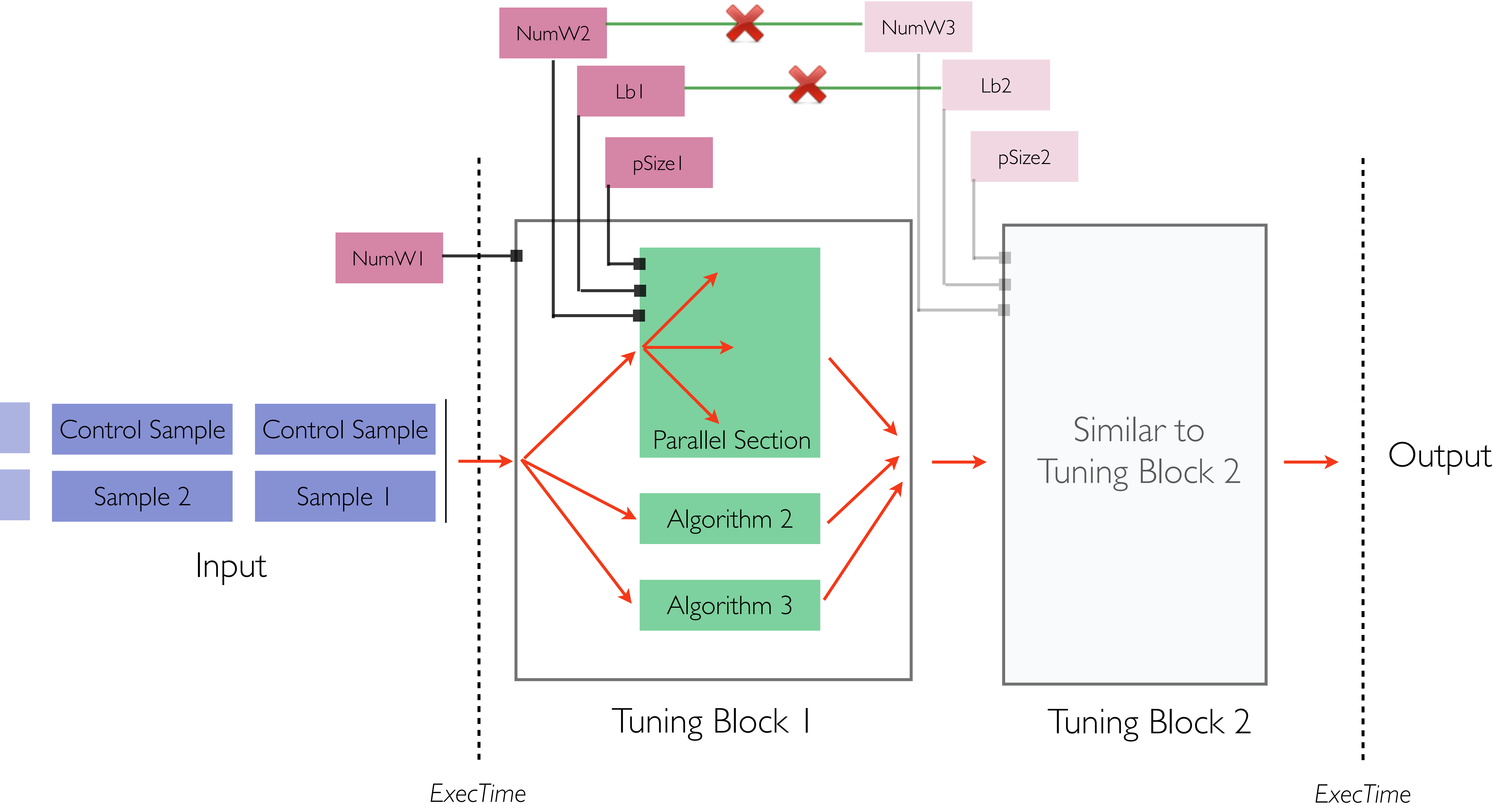

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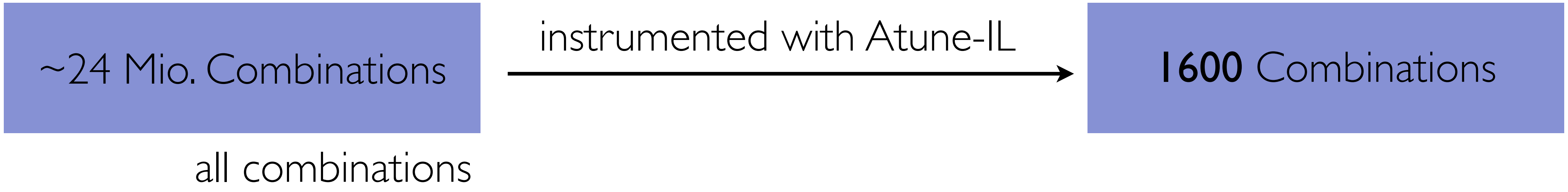
Case Study: Results I

- Search space reduction



~24 Mio. Combinations

all combinations

instrumented with Atune-IL

1600 Combinations

- Difference in execution time
  - 45% between the best and the worst configuration (8 core machine)

Case Study: Results 2

- Implementation effort

747 LOC

manually implemented

25 LOC

used Atune-IL

Related Work

- POET[1]
  - independent of application domain / host language
  - optimization on source code level
- XLanguage
  - #pragma approach
  - C / C++ code transformations
  - loop unrolling

[1] Parameterized Optimizing for Empirical Tuning

Pros and Cons

- ✓ Drastical search space reduction
- ✓ Host-language independent
- ✓ Independent of application domain
- ✓ Portability, maintenance

Pros and Cons

- ✓ Drastical search space reduction
- ✓ Host-language independent
- ✓ Independent of application domain
- ✓ Portability, maintenance

- Nothing available on the web
- Portability, maintenance
- Paper is incomplete / wrong
  - WEIGHT not specified
  - mixed START/DEFAULT
- LOC: hardly depends on programming style
  - template files ignored
- Section 6.4 „Results“ is weak