How Green are Java Best Practices?

Best Coding Practices and Software Eco-Design

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Overview

Eco-Design and Best Practices

Context and Issues

Context:

- ICT accounted 2% of carbon emissions in 2007
- Energy efficiency relies on hardware but not software
- Works on energy efficiency classes, energy-aware systems

Issues:

- Help developers to build energy-efficient software
  1. Detect energy-consuming patterns in source code
  2. Replace these patterns by energy-saving ones
- Qualify the energy impact for such best practices

Hypothesis and Objectives

Hypothesis

Best coding practices are eco-design rules

Objectives:

1. Formalizing Java best practices
2. Measuring savings of memory and energy at runtime
3. Evaluating confidence of such results

Formalizing Practices

Informal and Formal Examples

Best Coding Practice Example / Informal Rule:

String Literal Initialization

Initialization of strings with the keyword 'new' creates new objects. This is costly in time and memory space. Initializations with literal strings avoids this.

Informal and Formal Examples

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  2. Avoid *that*
  3. Replace *that* by *this*

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Informal and Formal Examples

Listing 1: Prefer String Literal Initialization

```
<rule id="prefer-string-literal-initialization">
  <title>Prefer string literal initialization</title>
  <description>
    Primitive type objects should be initialized with primitive values
    and without the use of any constructors.
  </description>
  <check green="StringValue" gray="StringObject" />
</rule>
```

Informal and Formal Examples

Listing 2: String Literal Initialization

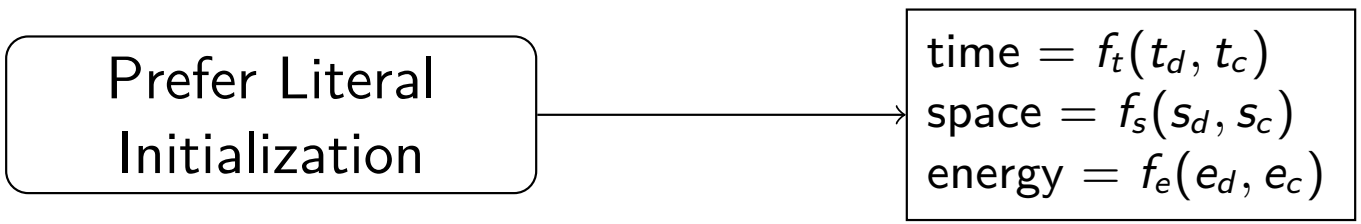
```
public class StringValue implements Code {

  private String[] array;

  public void setUp() {
    array = new String[1000];
  }

  public void doRun() throws Exception {
    for (int i = 0; i < 1000; i++) {
      array[i] = "abcdefg...";
    }
  }

  public void tearDown() {
    array = null;
  }

}
```

Informal and Formal Examples

Listing 3: String Object Initialization

```
public class StringObject implements Code {

  private String[] array;

  public void setUp() {
    array = new String[1000];
  }

  public void doRun() throws Exception {
    for (int i = 0; i < 1000; i++) {
      array[i] = new String("abcdefg...");
    }
  }

  public void tearDown() {
    array = null;
  }

}
```

Time, Space, Energy Semantics



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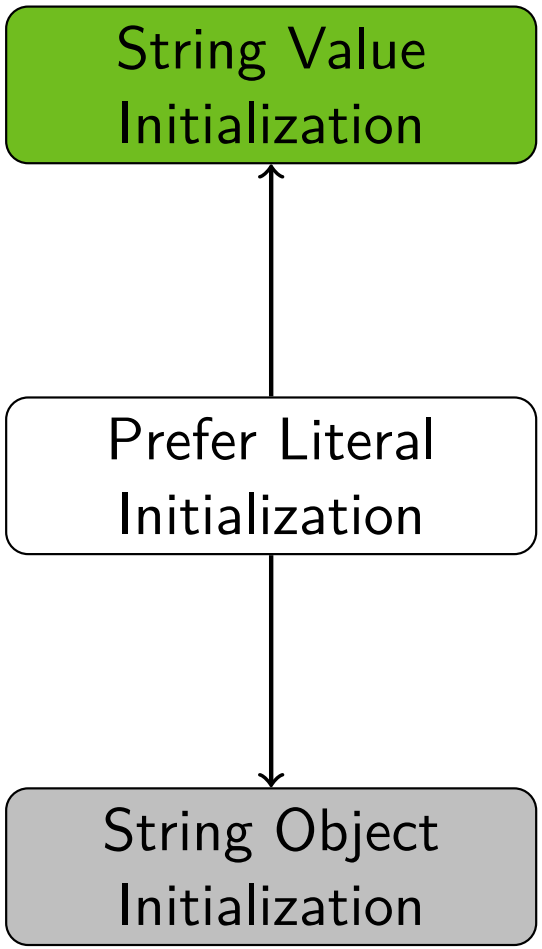
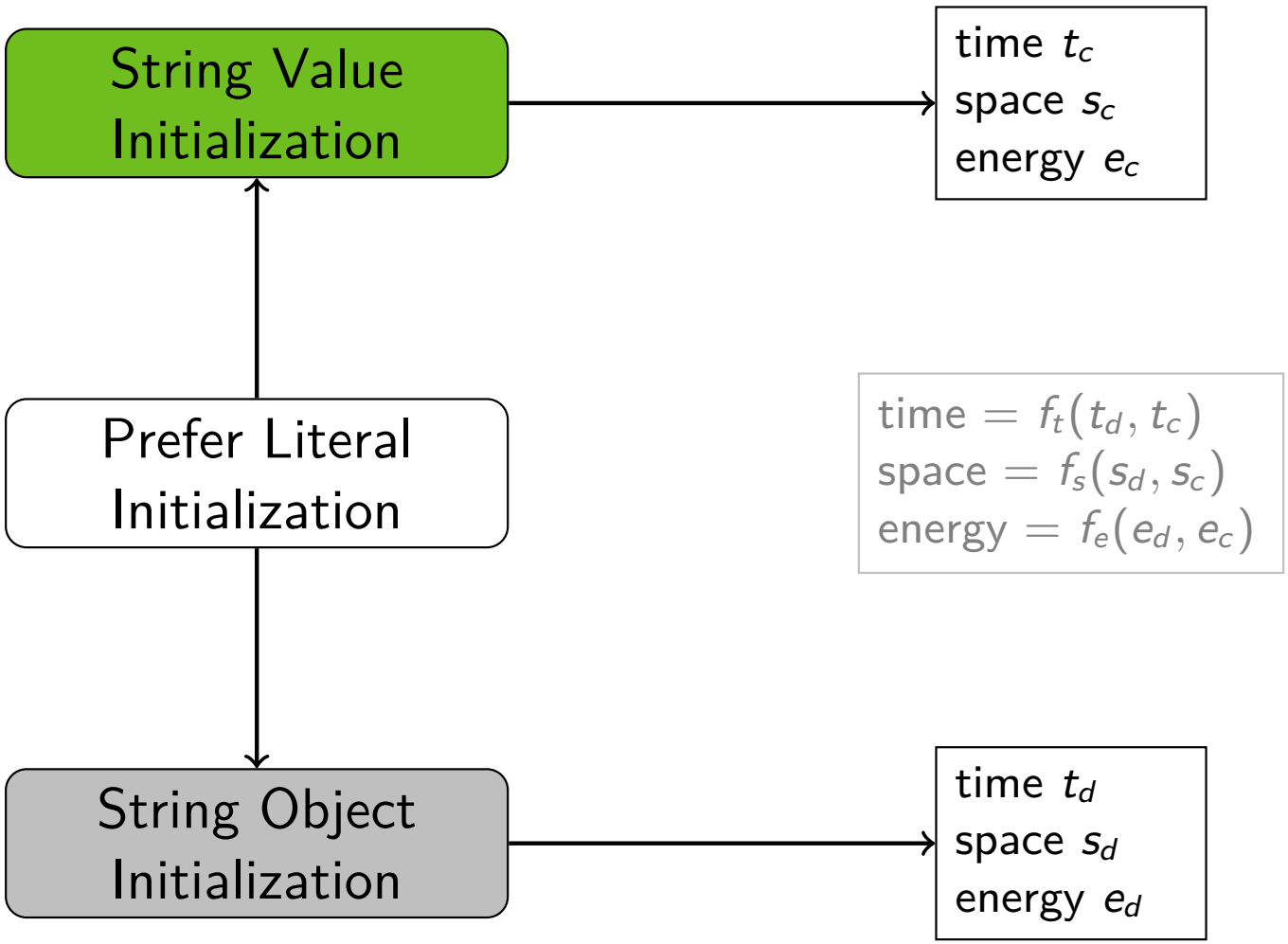


$$\text{time} = f_t(t_d, t_c)$$
$$\text{space} = f_s(s_d, s_c)$$
$$\text{energy} = f_e(e_d, e_c)$$

Time, Space, Energy Semantics



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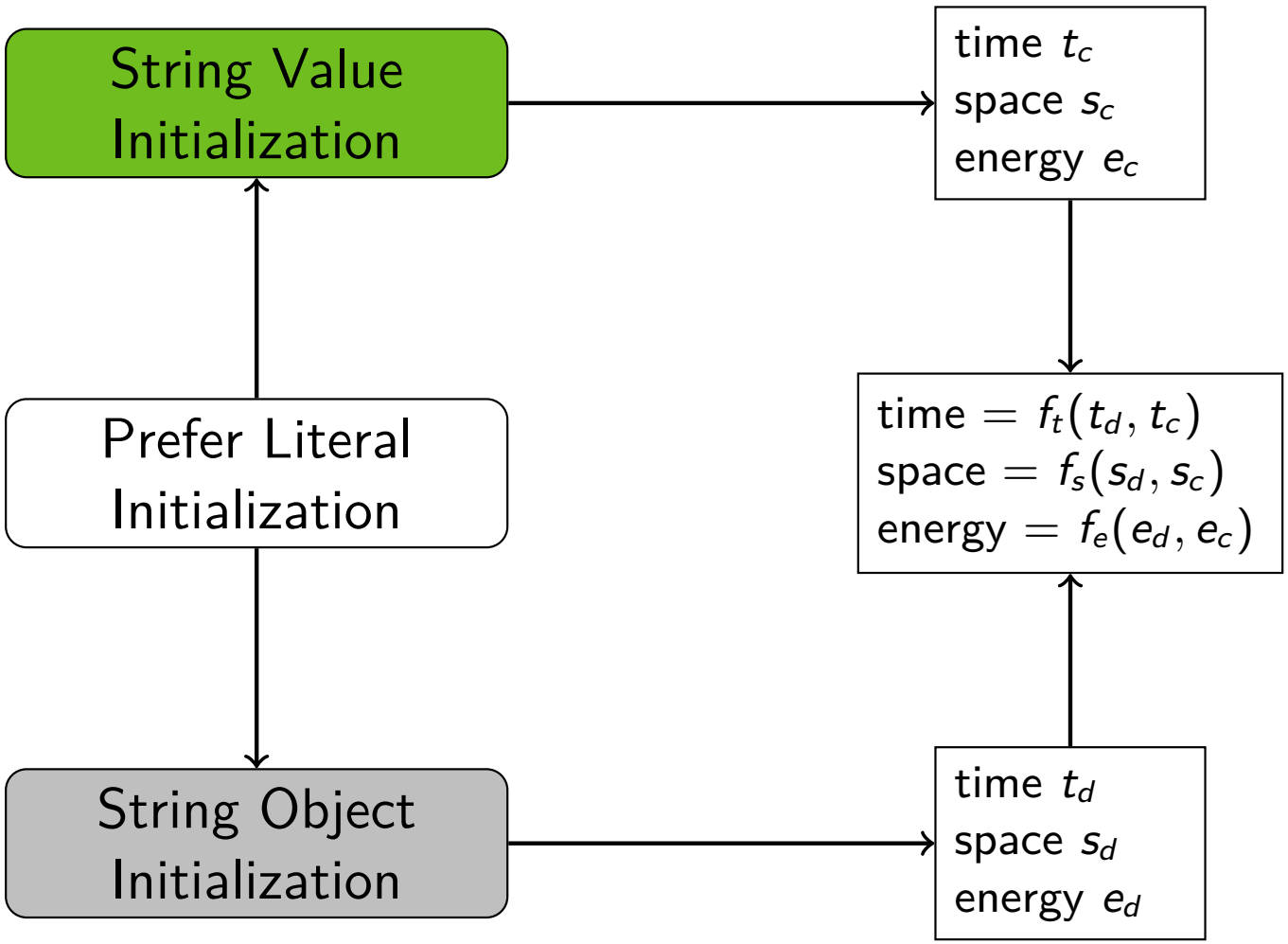
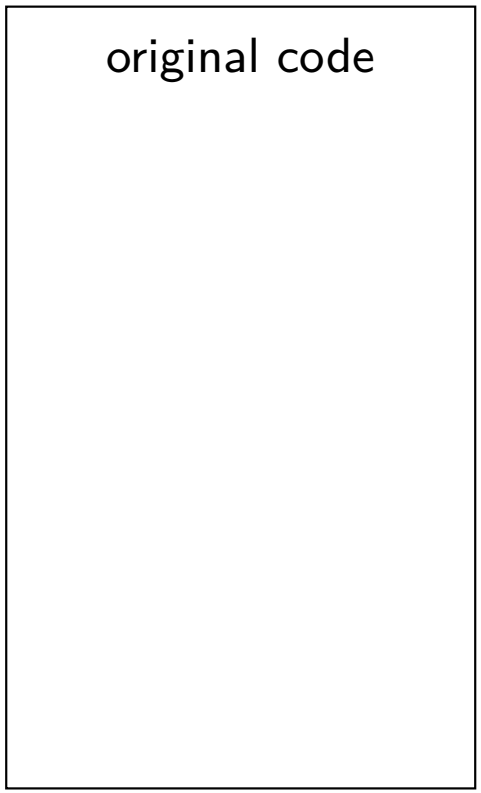


Time, Space, Energy Semantics

Goal: statistical static analysis method and tools



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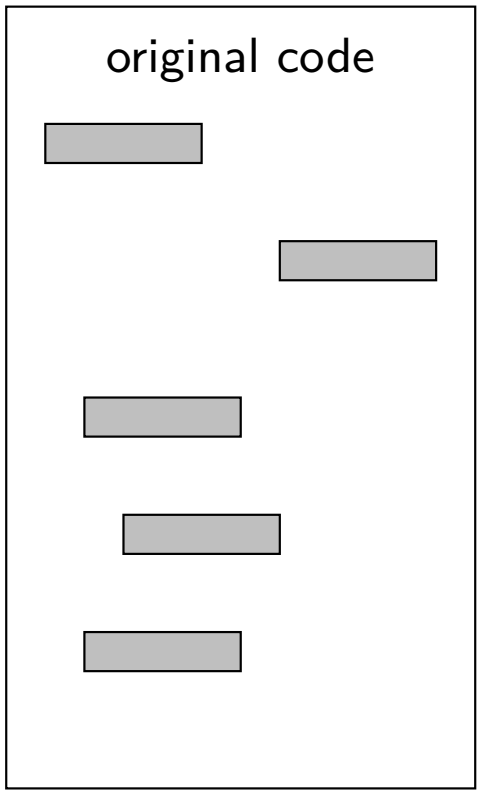

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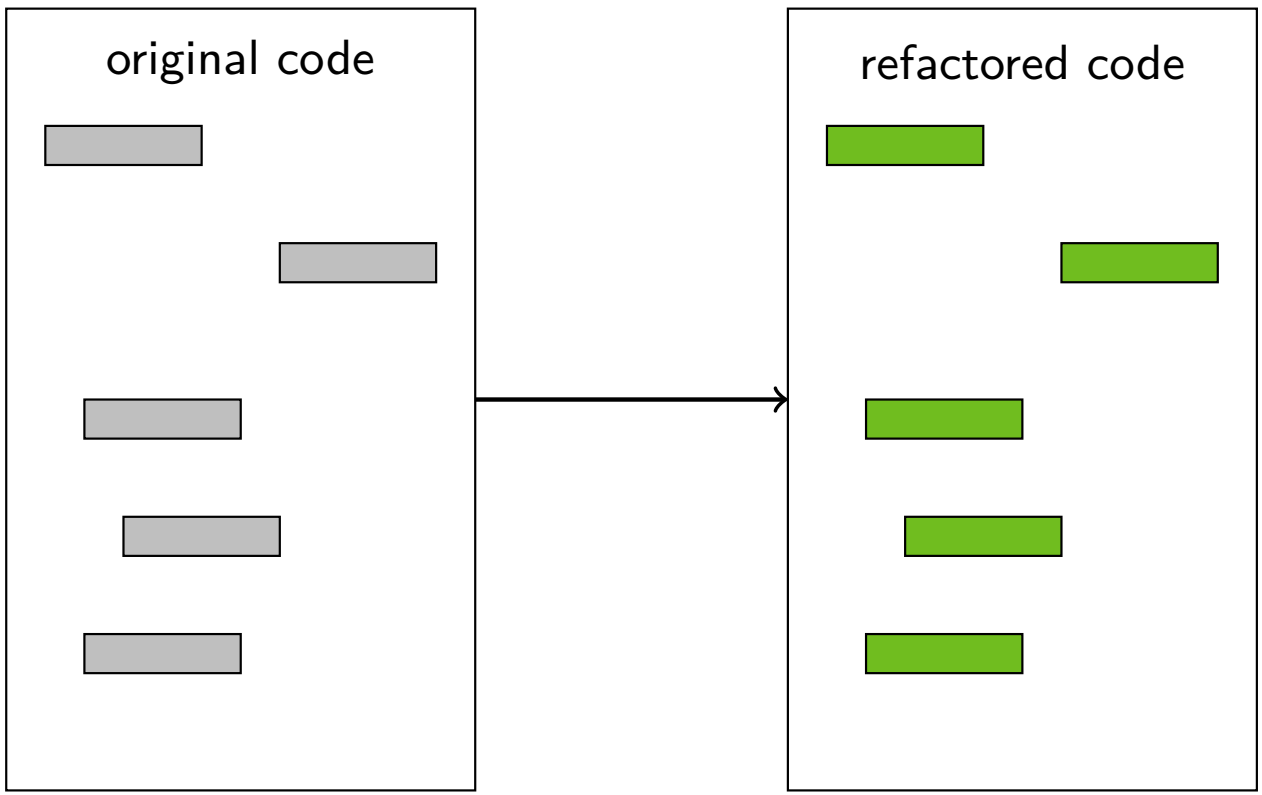

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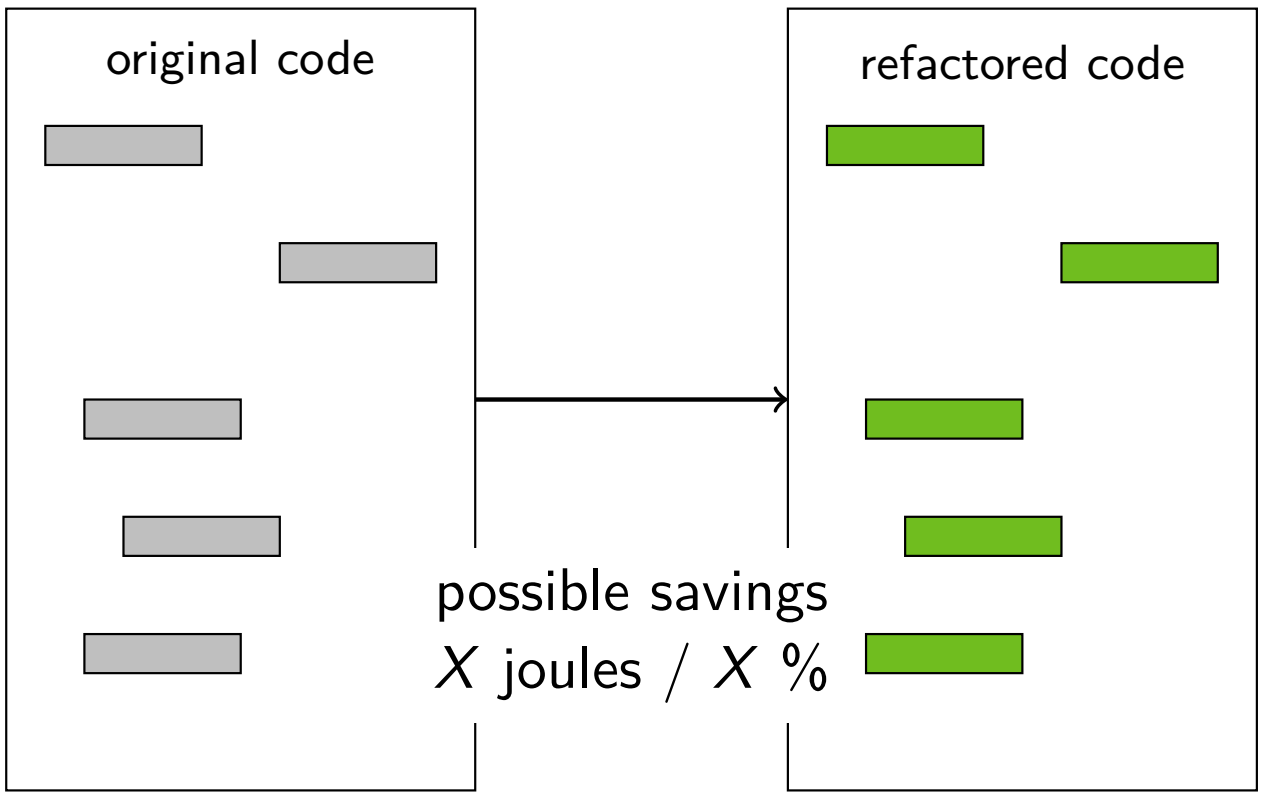

Measuring Codes

Needs and Requirements

Needs:

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Needs:

- power-meter with digital outputs

Requirements:

- power-meter with fine-grain precision

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- platform for running Java codes

Requirements:

- power-meter with fine-grain precision
- Java micro-benchmarking to avoid JIT

Needs and Requirements

Needs:

- power-meter with digital outputs
- memory monitor with digital outputs
- platform for running Java codes
- system for managing codes and measures

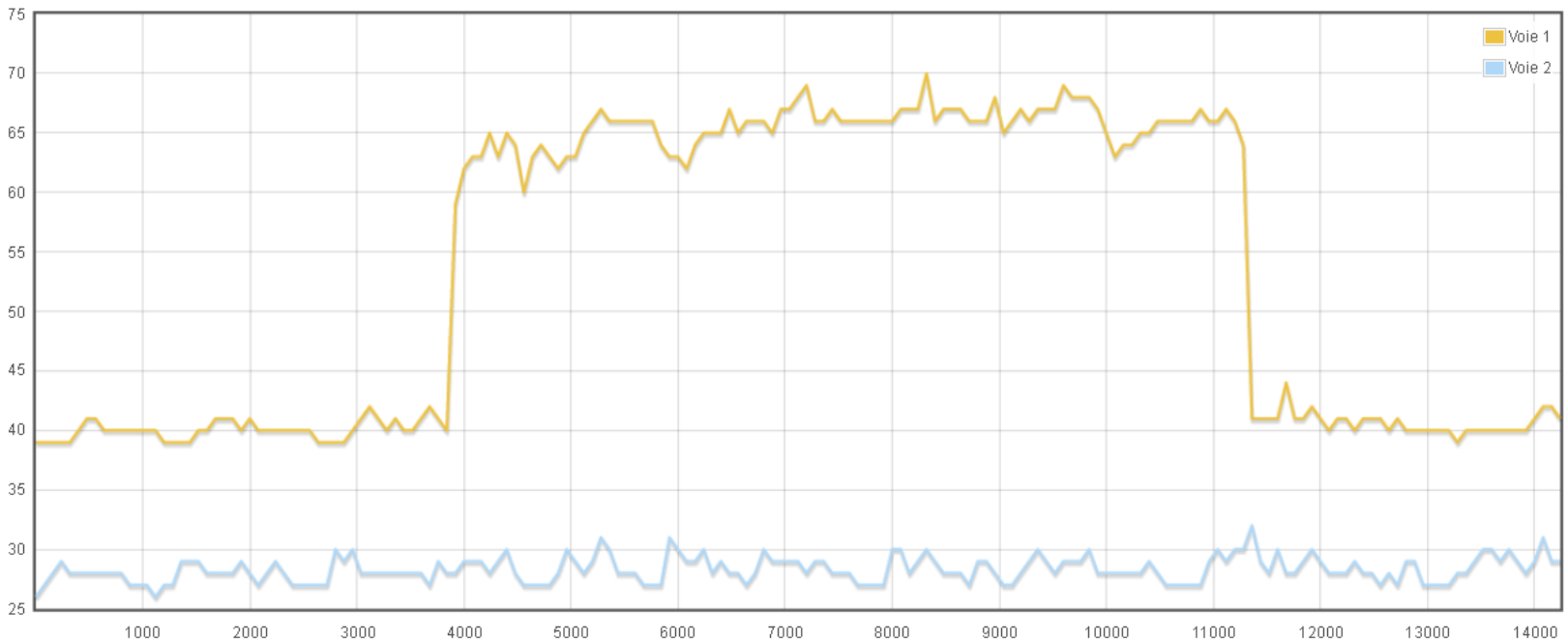
Requirements:

- power-meter with fine-grain precision
- Java micro-benchmarking to avoid JIT
- system able to manage physical and logical sensors

Measure Task and Process

Measurement Protocol:

1. 4 seconds idle
2. 10 seconds execution time
3. 3 seconds idle

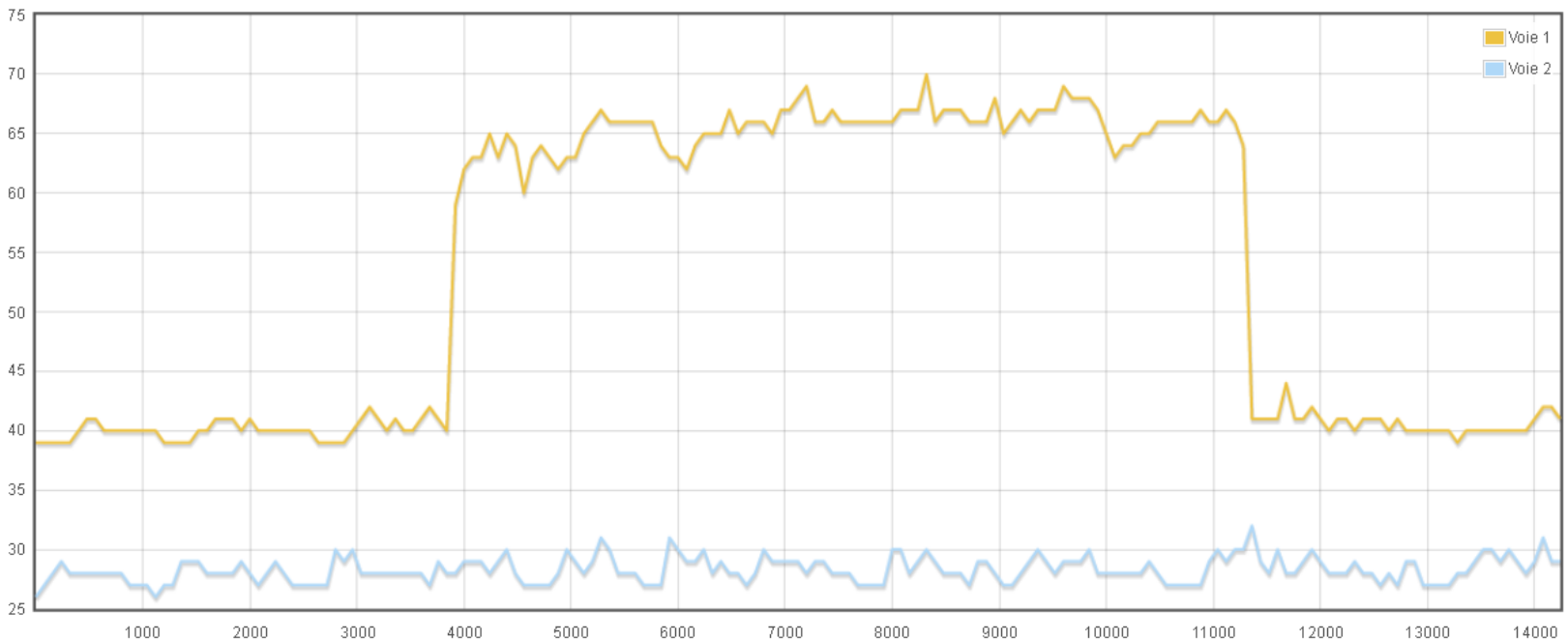


Measure Task and Process

Semantics based on quantitative metrics:

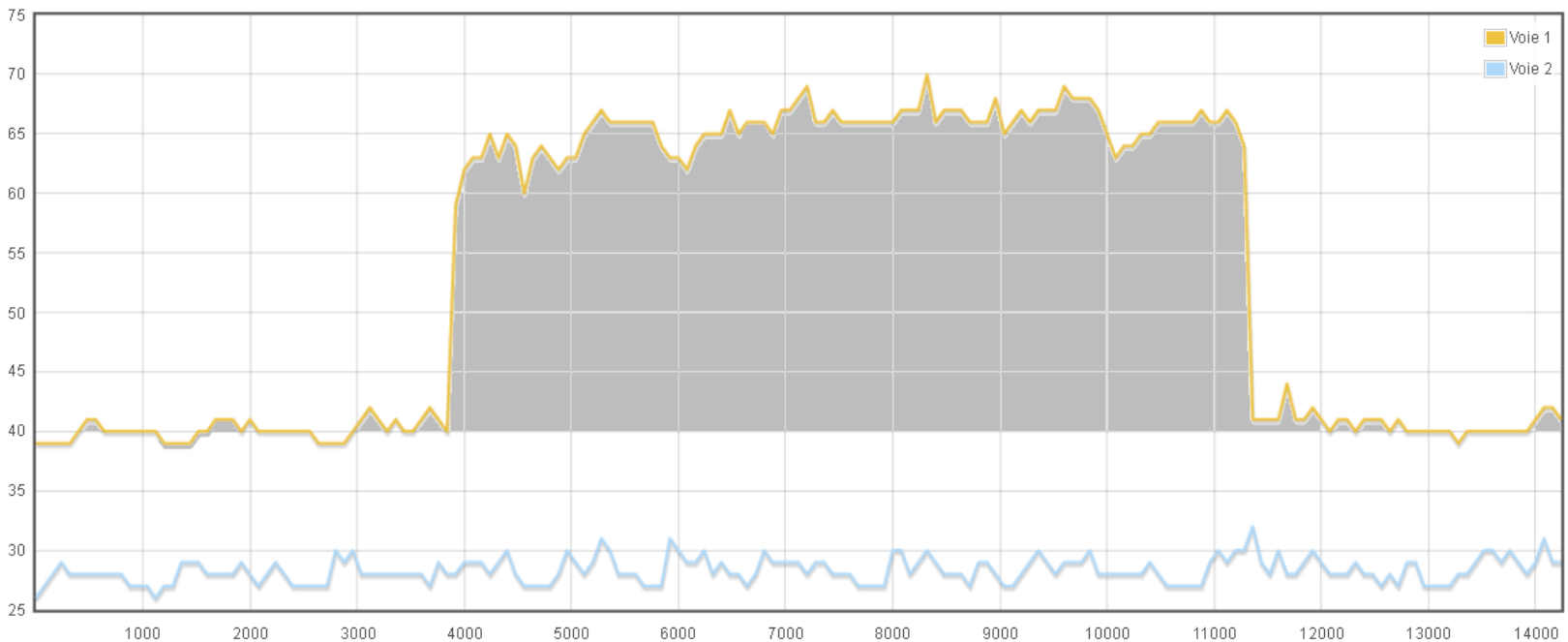
x-axis execution time

y-axis instant power or instant memory space



Measure Task and Process

Preliminary Computations:



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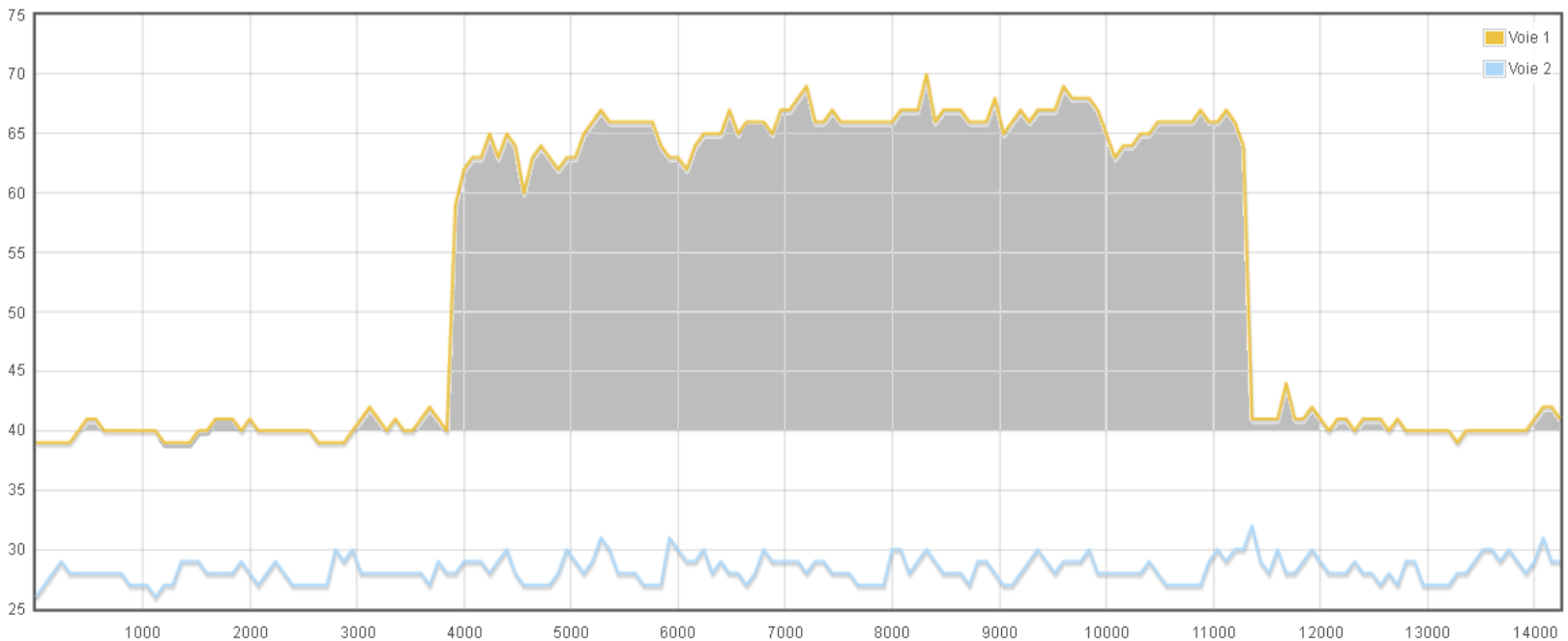
Preliminary Computations:

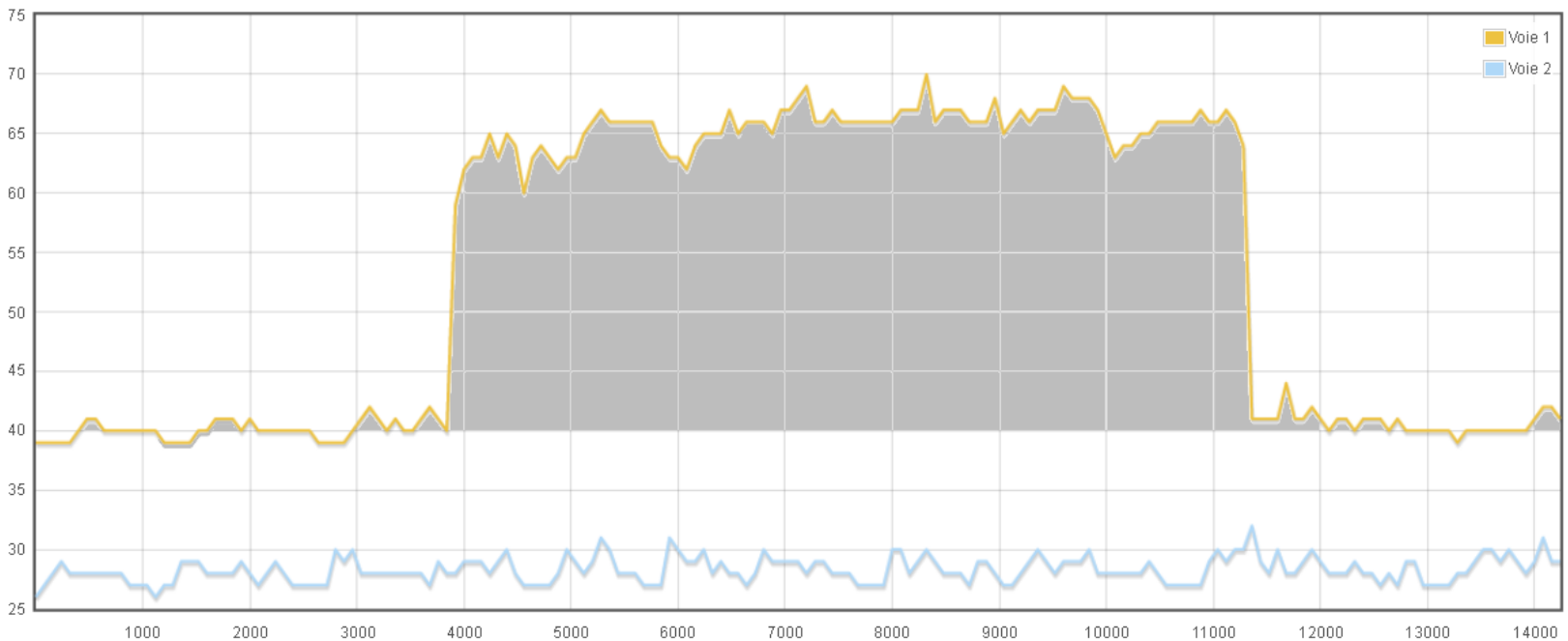
- total energy obtained by the trapezoidal rule



Measure Task and Process

Preliminary Computations:

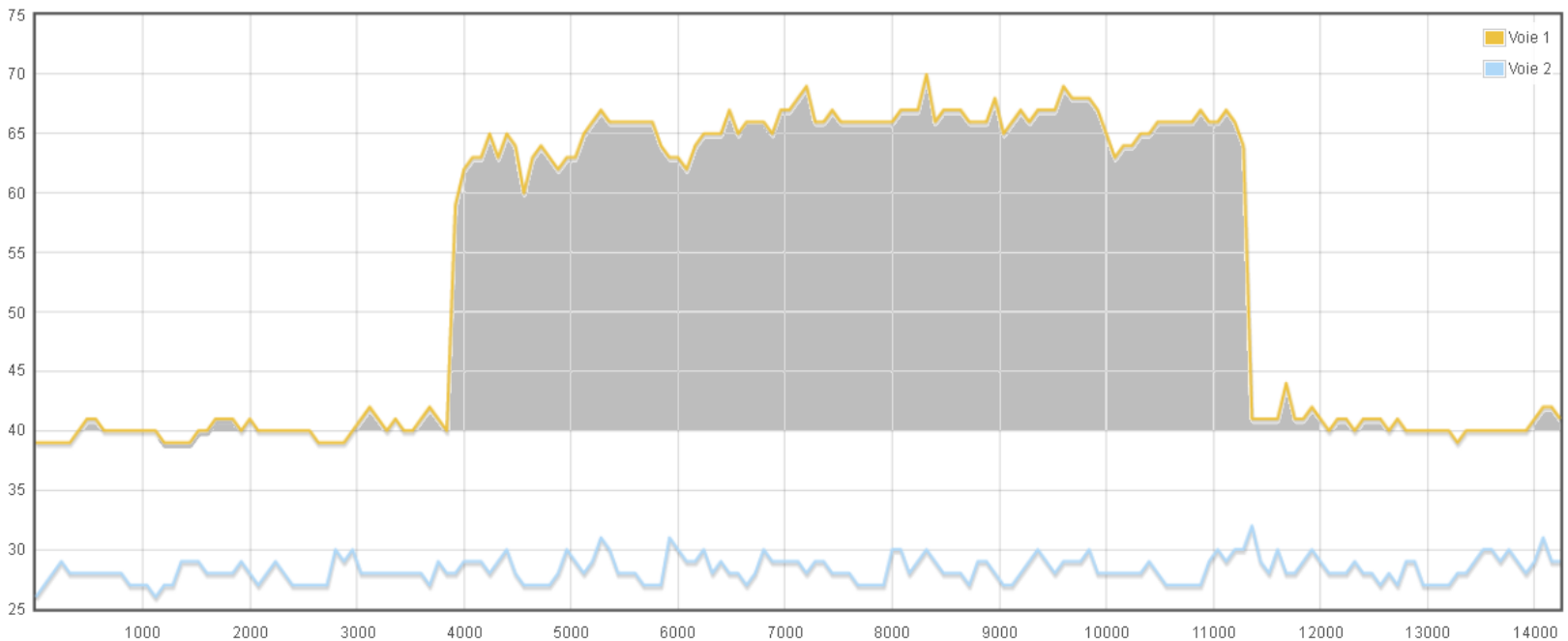
- total energy obtained by the trapezoidal rule
- idle power = average of the first 4 second instant powers



Measure Task and Process

Preliminary Computations:

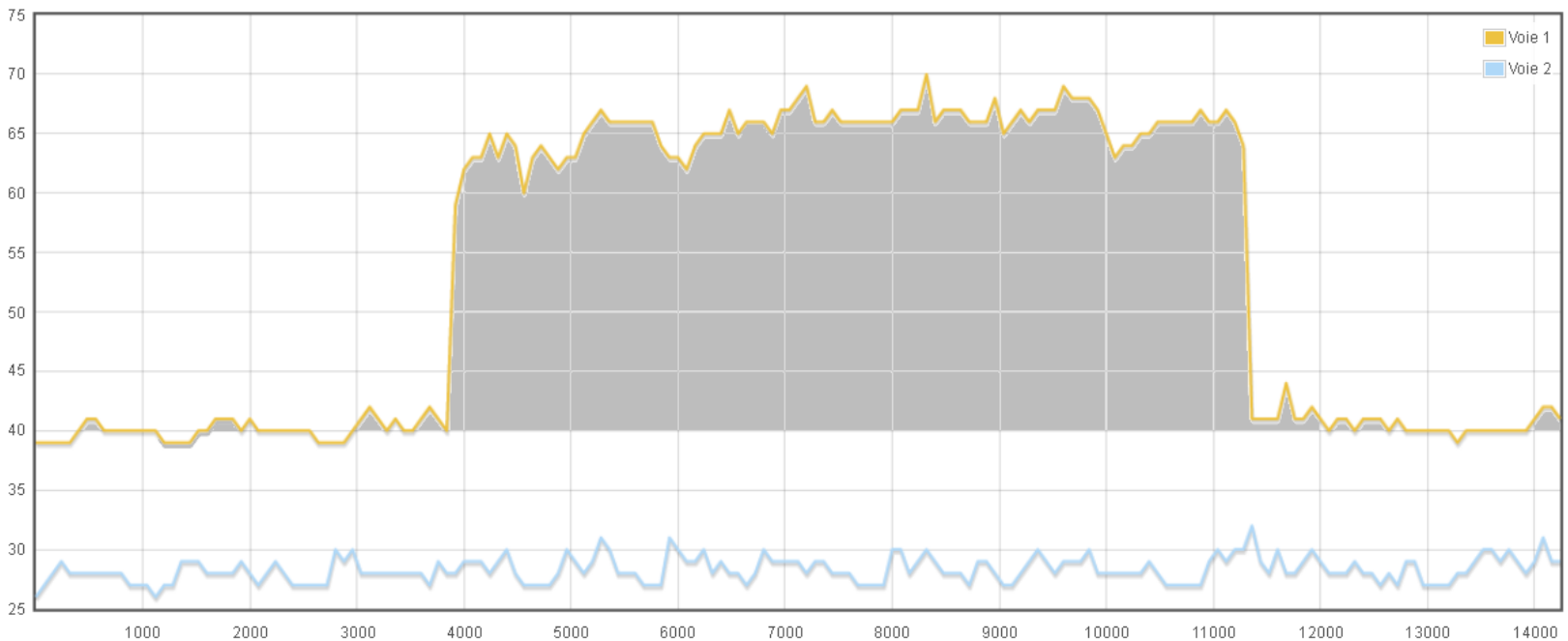
- total energy obtained by the trapezoidal rule
- idle power = average of the first 4 second instant powers
- idle energy = idle power × protocol time



Measure Task and Process

Code energy computation and normalization:

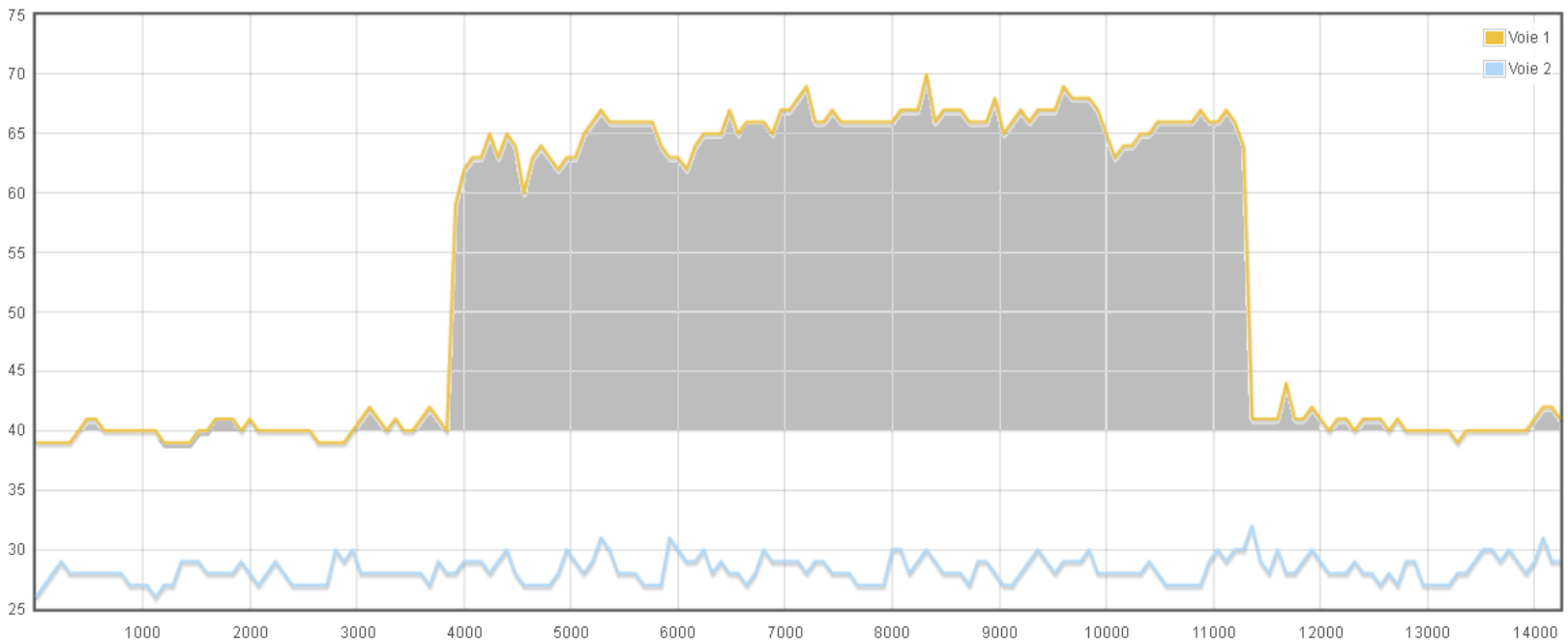
- code energy = total energy - idle energy



Measure Task and Process

Code energy computation and normalization:

- code energy = total energy - idle energy
- normalized code energy = code energy / times of execution



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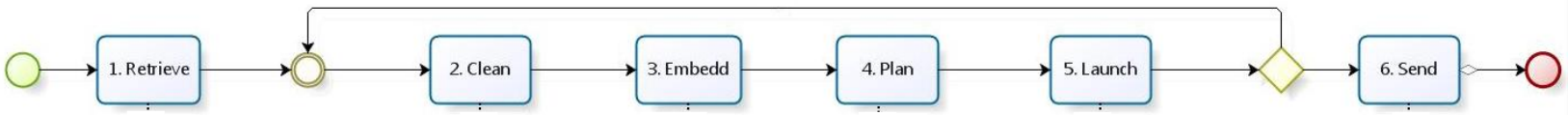

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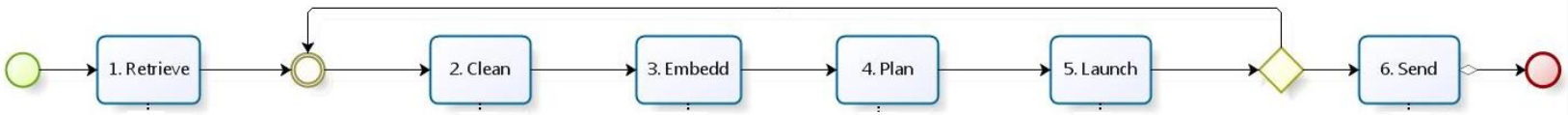

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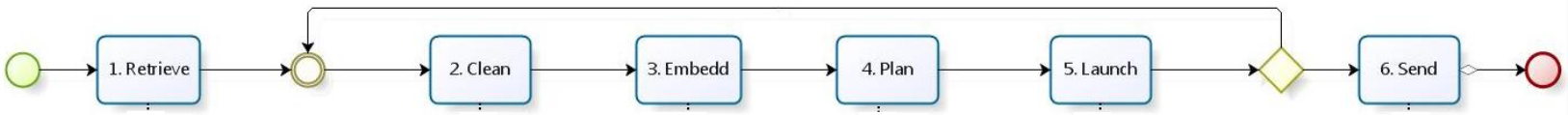
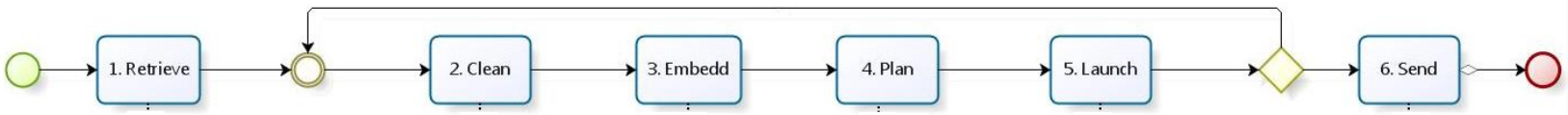


1. Retrieve an available Java code
2. Iterate while this code isn't mature:

Measure Task and Process

Measure Process:



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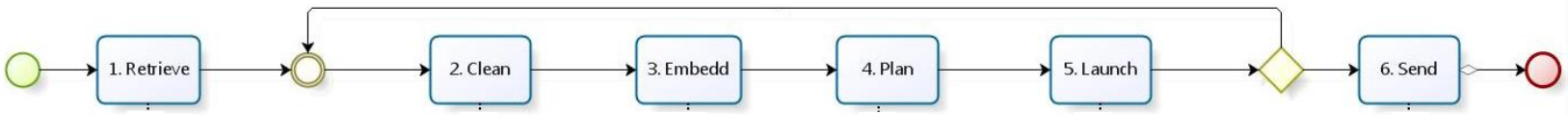

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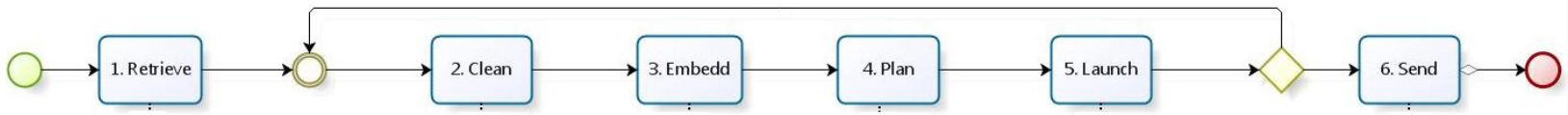

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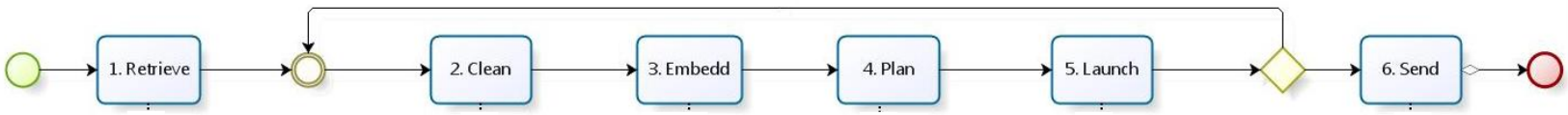
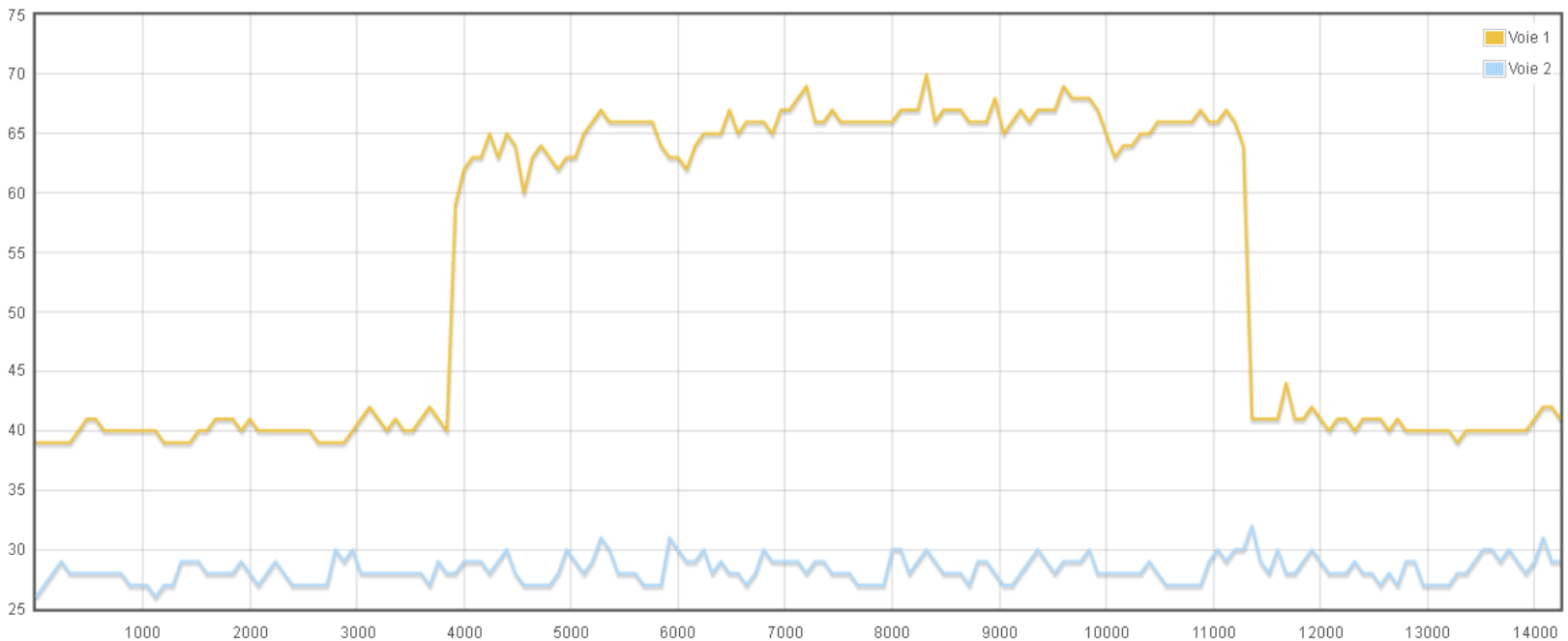


1. Retrieve an available Java code
2. Iterate while this code isn't mature:
   - Clean its measure set
   - Compute its maturity
   - Plan new measures if required
   - Perform these measures
3. Send the report of this code

Analyzing Measures, Codes, Practices

Clean and Canonical Measures

3 kinds of measure disturbances:



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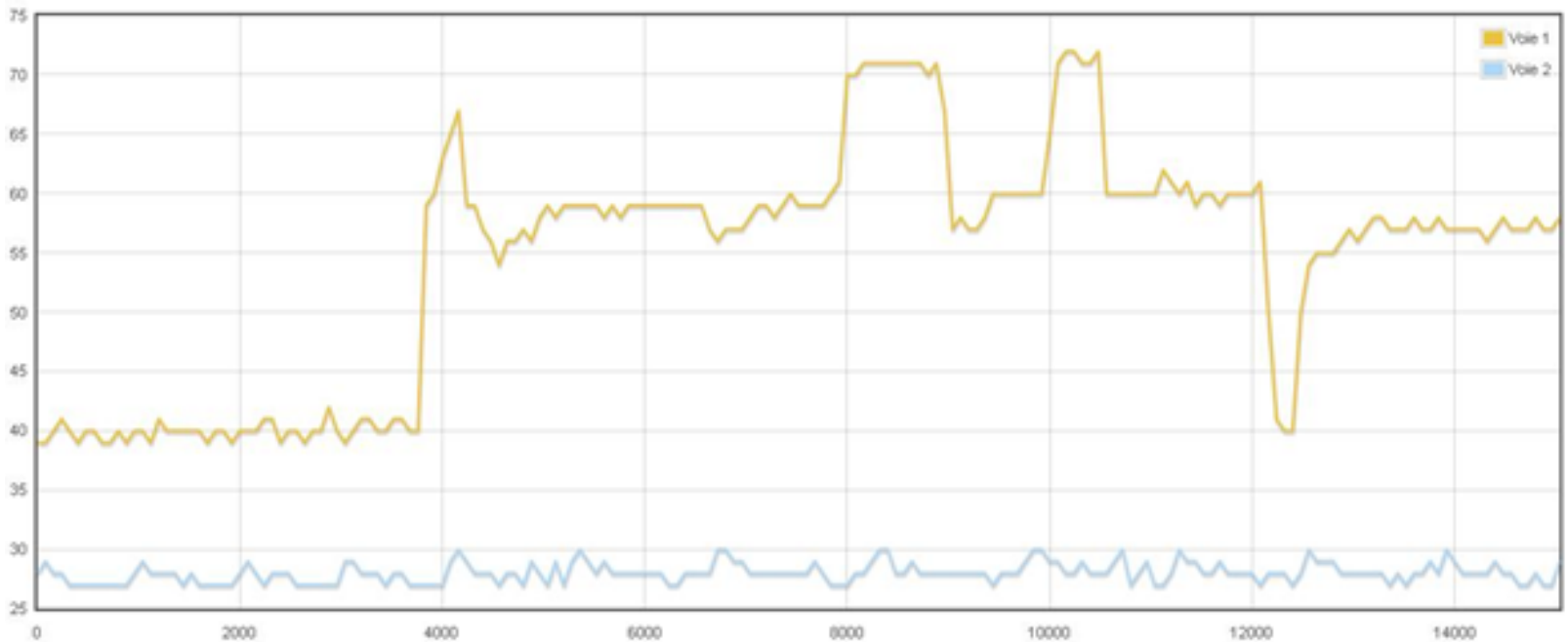

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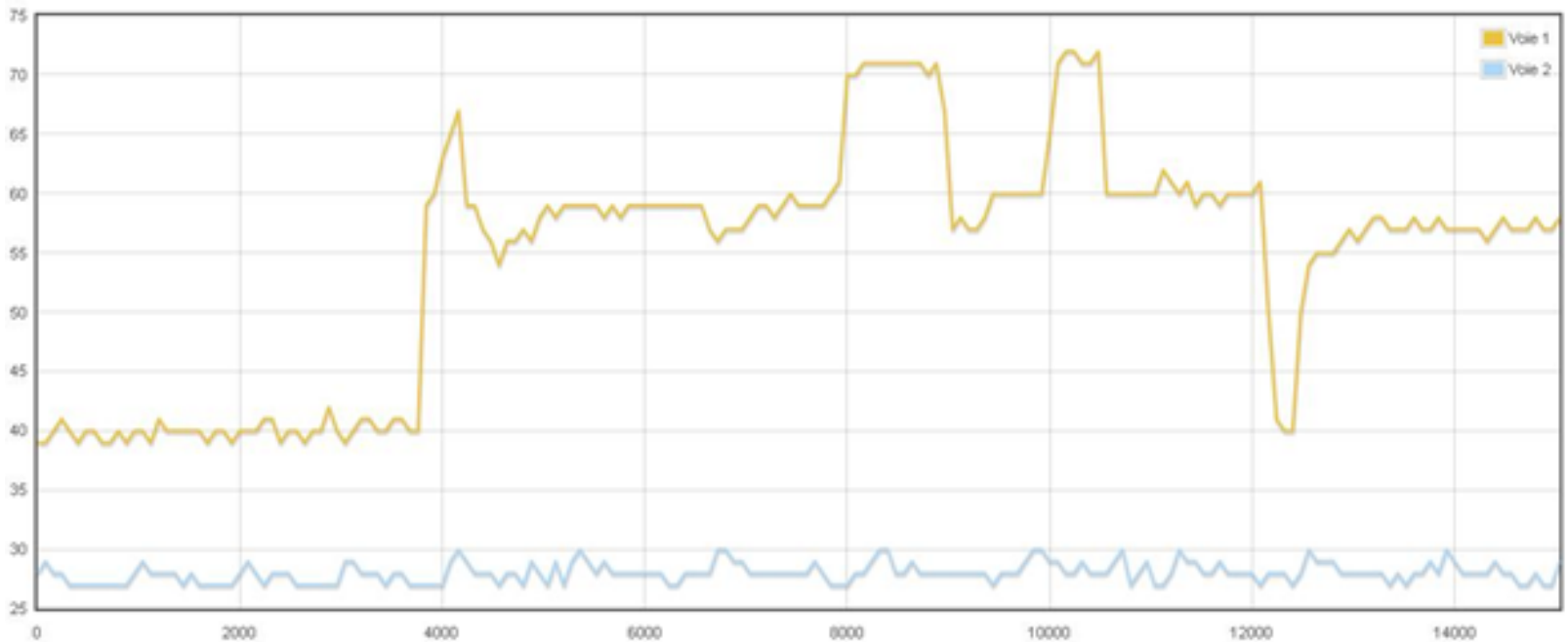

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Cleaning algorithm evaluation:

- 200 measures annotated by 3 experts

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- split-and-merge algorithm
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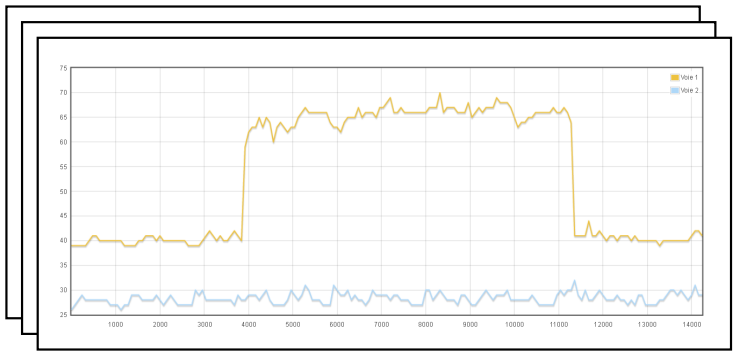
  - recall: 1.0
  - **remove all disturbed measures**

Clean and Canonical Measures

Canonical measure:



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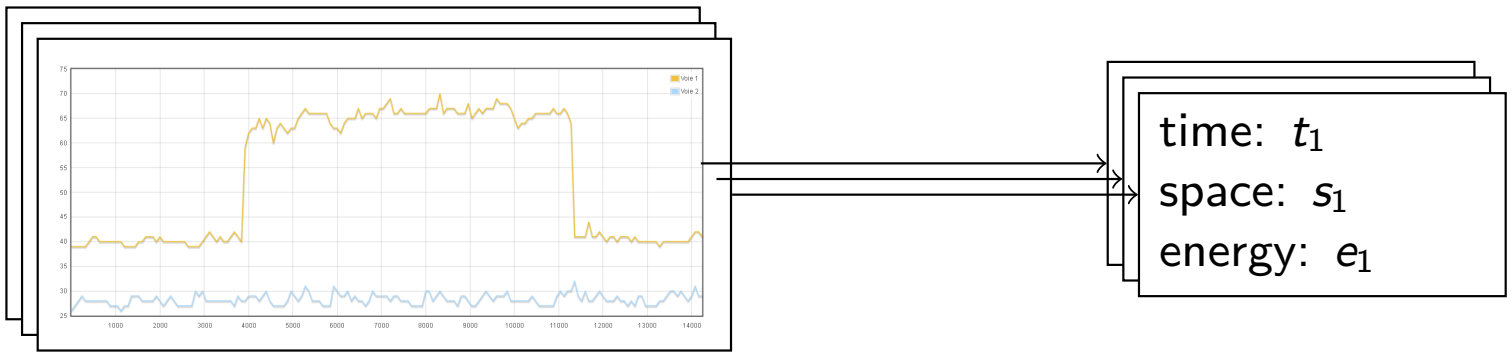

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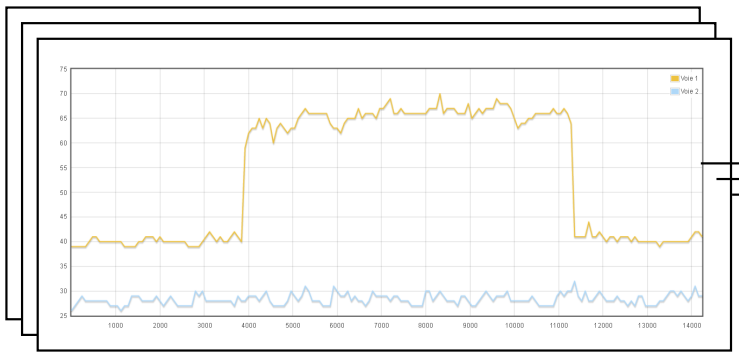

time: t_1
space: s_1
energy: e_1

time: t
space: s
energy: e

Clean and Canonical Measures

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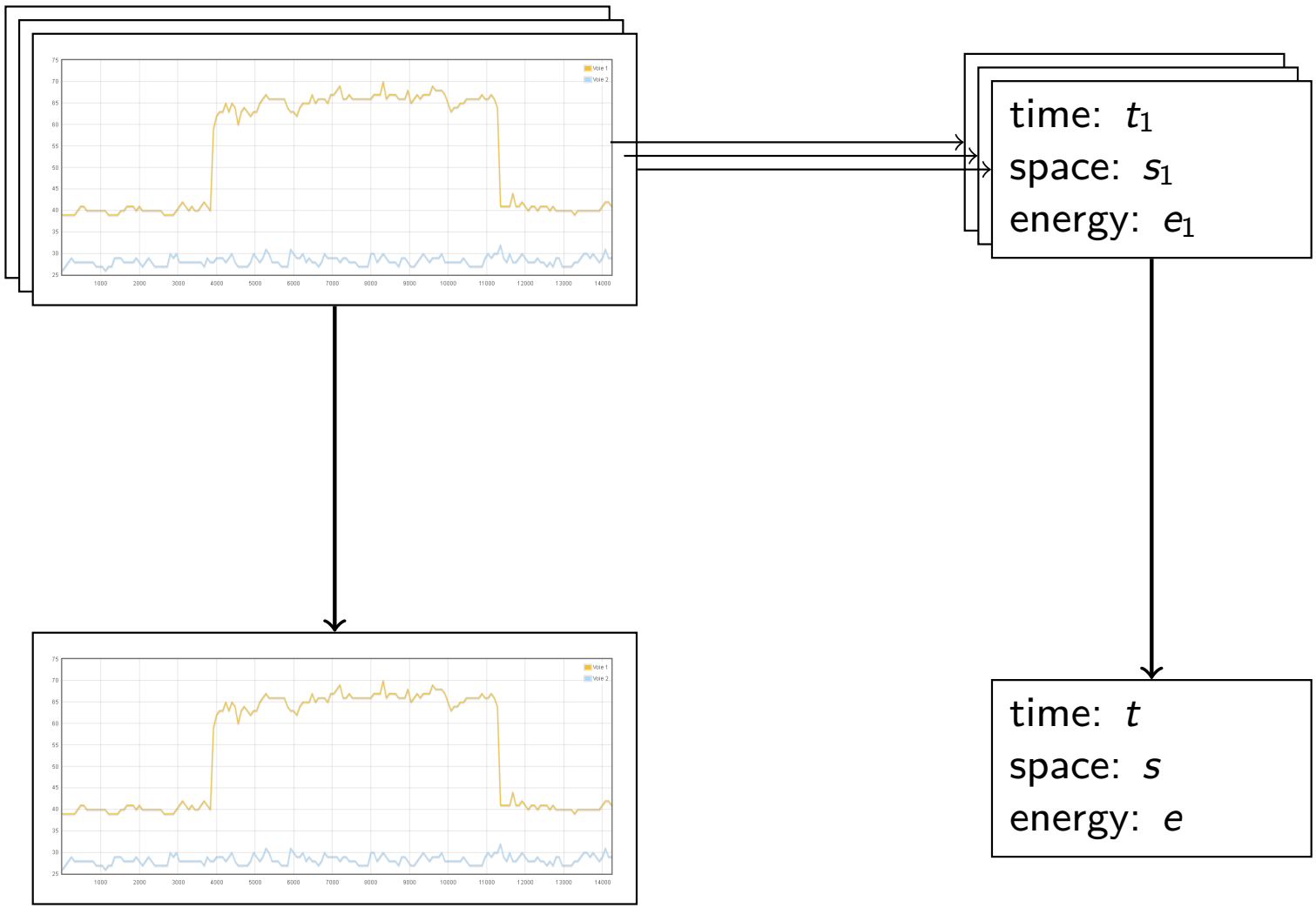

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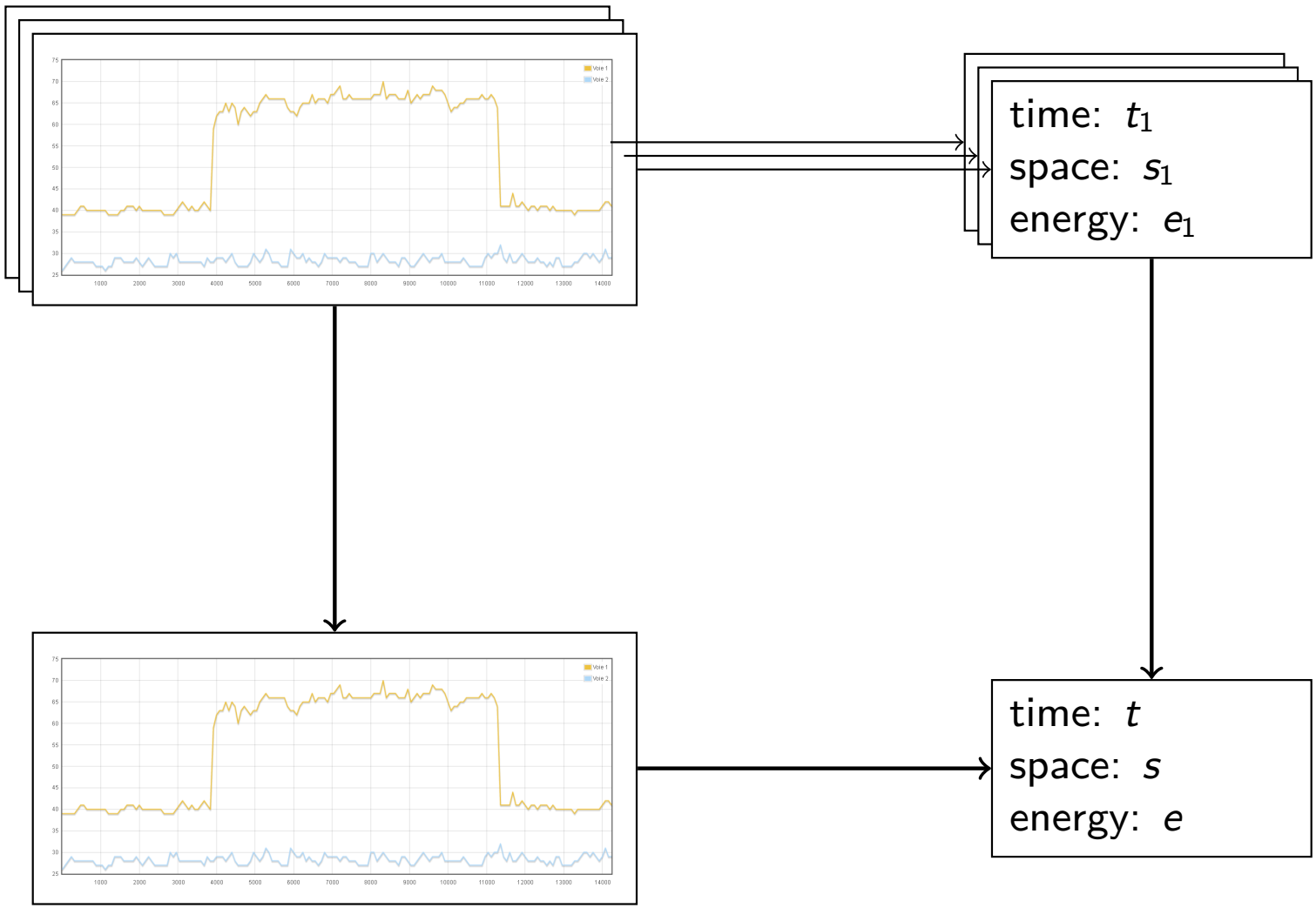

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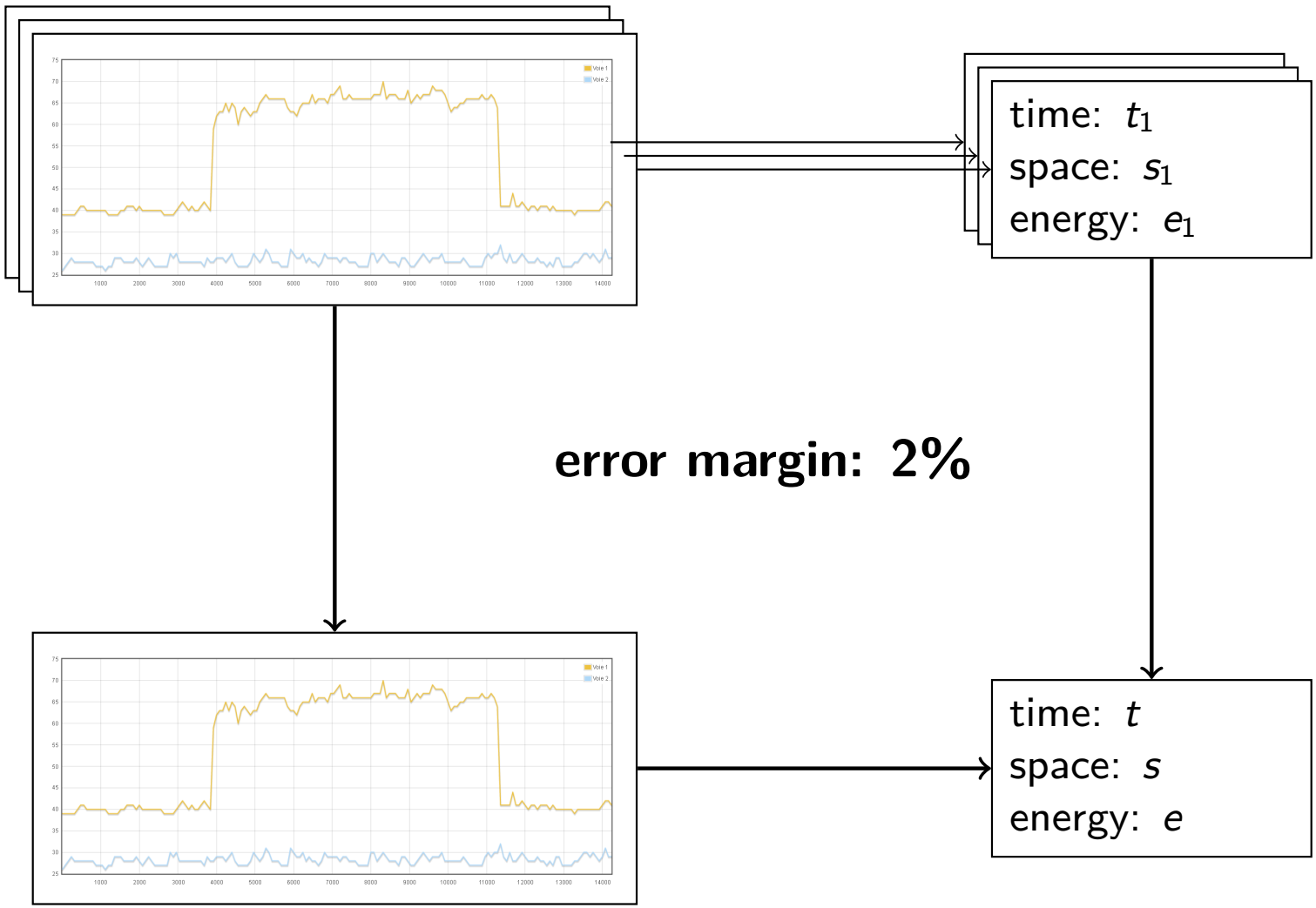

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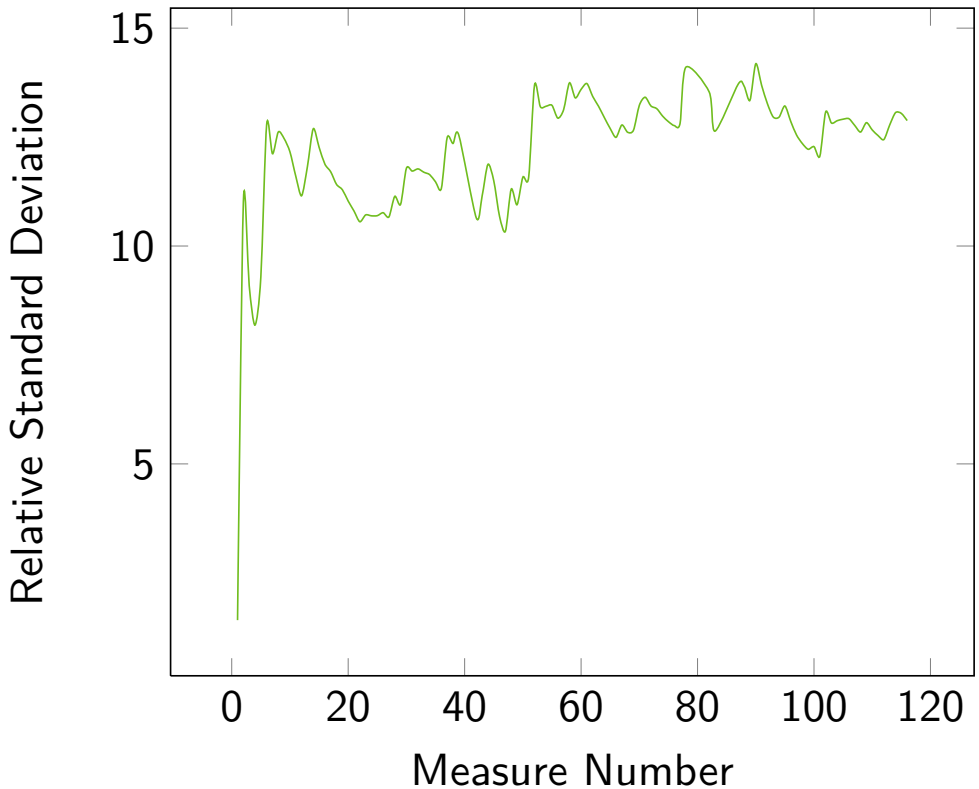

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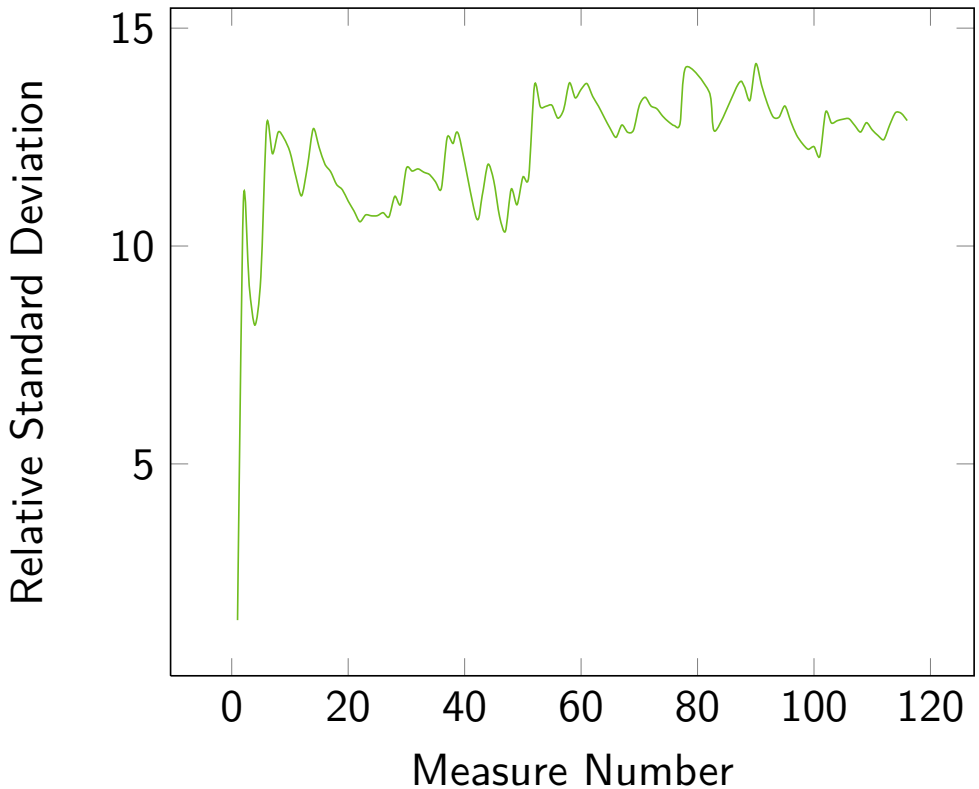

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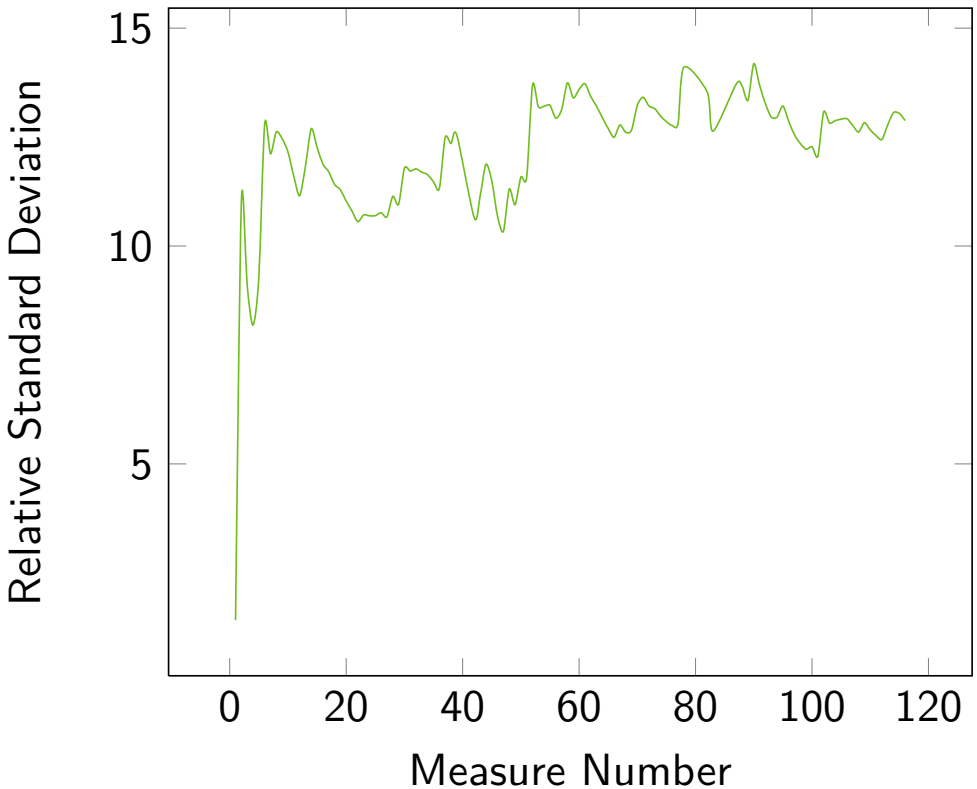

- a set of 25 measures minimum
- a standard deviation less than 10%

Results

Replace Object Initialization by Literal Initialization

- Energy in nanojoules, time in nanoseconds
- Memory in kilobytes
- Standard Deviation on Energy

	Green Energy	*Gray Energy*	*Green Time*	*Gray Time*	*Green Memory*	*Gray Memory*	*Green StdDev*	*Gray StdDev*
String	697	7885	842	7827	4136	36104	4.40%	8.14%
Float	10311	10448	4736	4127	20032	20032	5.85%	6.58%
Integer	685	9575	833	4591	4048	20032	5.21%	6.51%
Boolean	683	6267	775	4741	4048	20032	4.77%	7.03%
Char	695	33067	840	4595	4048	20032	5.04%	4.65%
Double	10003	10210	5810	4270	28032	28032	5.58%	7.83%
Long	669	8236	807	6066	4056	28032	2.89%	5.32%
Short	680	7819	819	3846	4048	20031	4.87%	7.71%

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   - 16 rules with no savings! (gain $\leqslant 0\%$)
   - 24 rules with few savings ($0\% <$ gain $\leqslant 10\%$)
   - 48 rules with strong savings (gain $> 10\%$)
2. 1 reliable measure system

Eco-Design Indicators

1. 88 formalized and measured rules
   - 16 rules with no savings! (gain $\leqslant 0\%$)
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robust	automatic iterative process
extensible	programming API

Future

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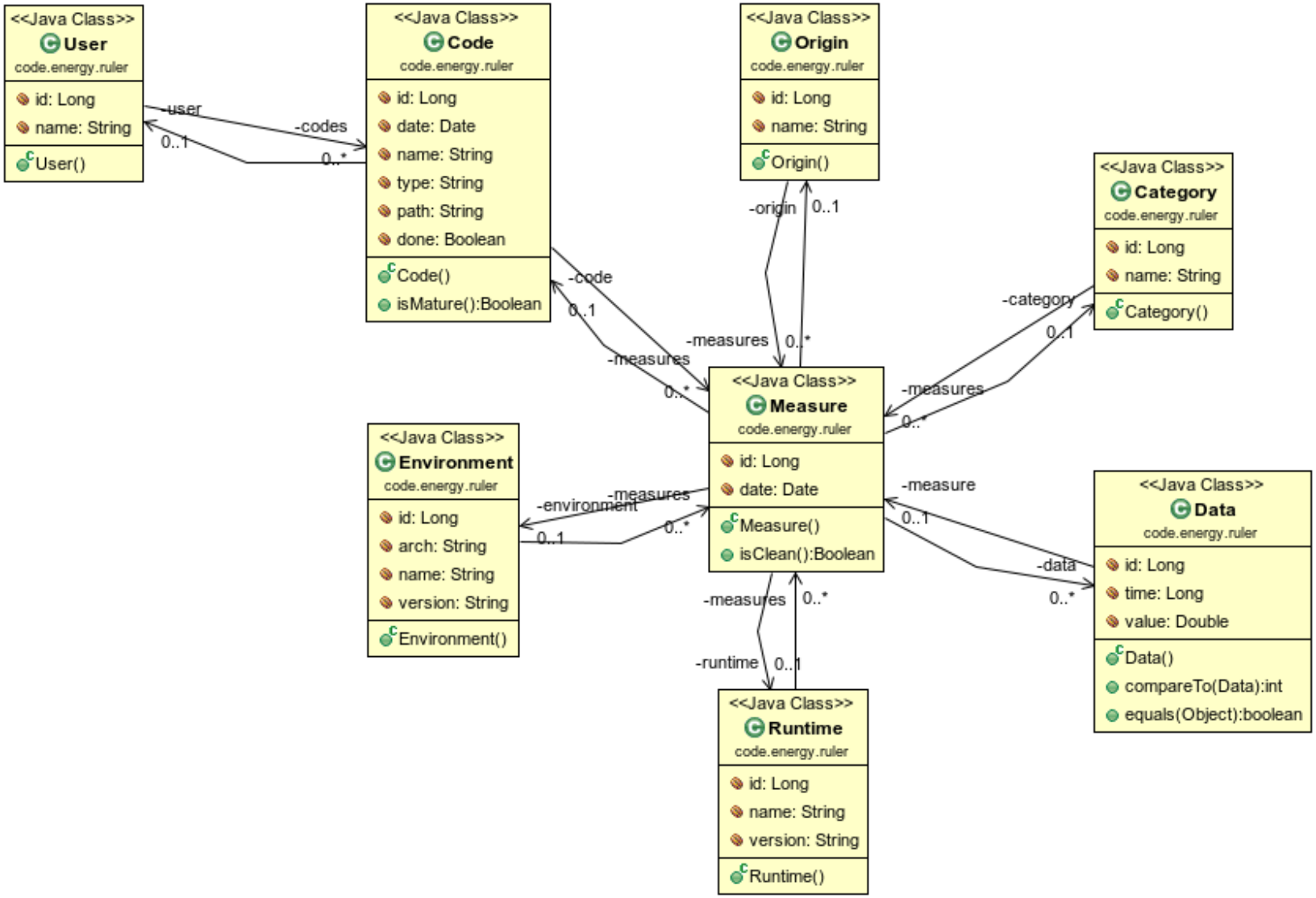
5. Energy efficiency of different programming languages
6. Accuracy of different physical and/or logical sensors
7. Energy and memory footprints of logical sensors

Thank you

Data Model


<<Java Class>>
User
code.energy.ruler
id: Long
name: String
User()
<<Java Class>>
Code
code.energy.ruler
id: Long
date: Date
name: String
type: String
path: String
done: Boolean
Code()
isMature():Boolean
<<Java Class>>
Origin
code.energy.ruler
id: Long
name: String
Origin()
<<Java Class>>
Category
code.energy.ruler
id: Long
name: String
Category()
<<Java Class>>
Measure
code.energy.ruler
id: Long
date: Date
Measure()
isClean():Boolean
<<Java Class>>
Environment
code.energy.ruler
id: Long
arch: String
name: String
version: String
Environment()
<<Java Class>>
Data
code.energy.ruler
id: Long
time: Long
value: Double
Data()
compareTo(Data):int
equals(Object):boolean
<<Java Class>>
Runtime
code.energy.ruler
id: Long
name: String
version: String
Runtime()
-user
0..1
-codes
0..*
-code
0..1
-origin
0..1
-measures
0..*
-category
0..1
-environment
0..1
-measure
0..1
-data
0..*
-runtime
0..1