Phase-based Adaptive Recompilation in a JVM

Dayong Gu   Clark Verbrugge

Sable Research Group, School of Computer Science
McGill University, Montréal, Canada
{dgu1, clump}@cs.mcgill.ca

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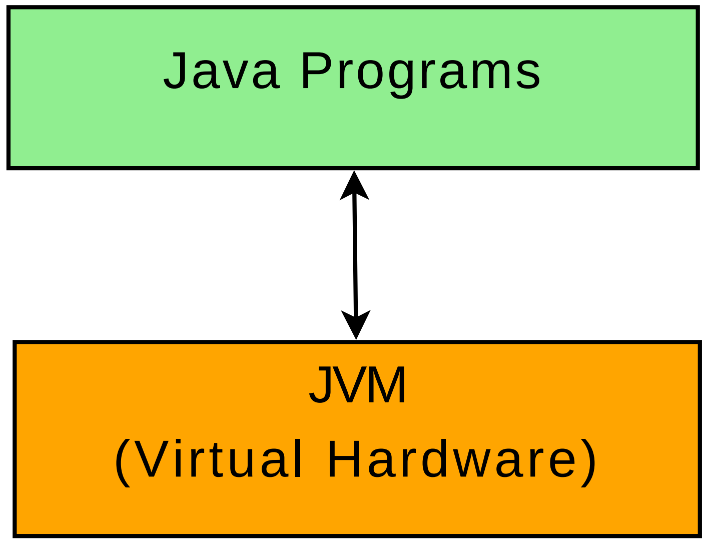
Outline

1. Motivation
2. Hardware Information Analysis
3. Adaptive Recompilation
4. Conclusions and Future Work

Motivation



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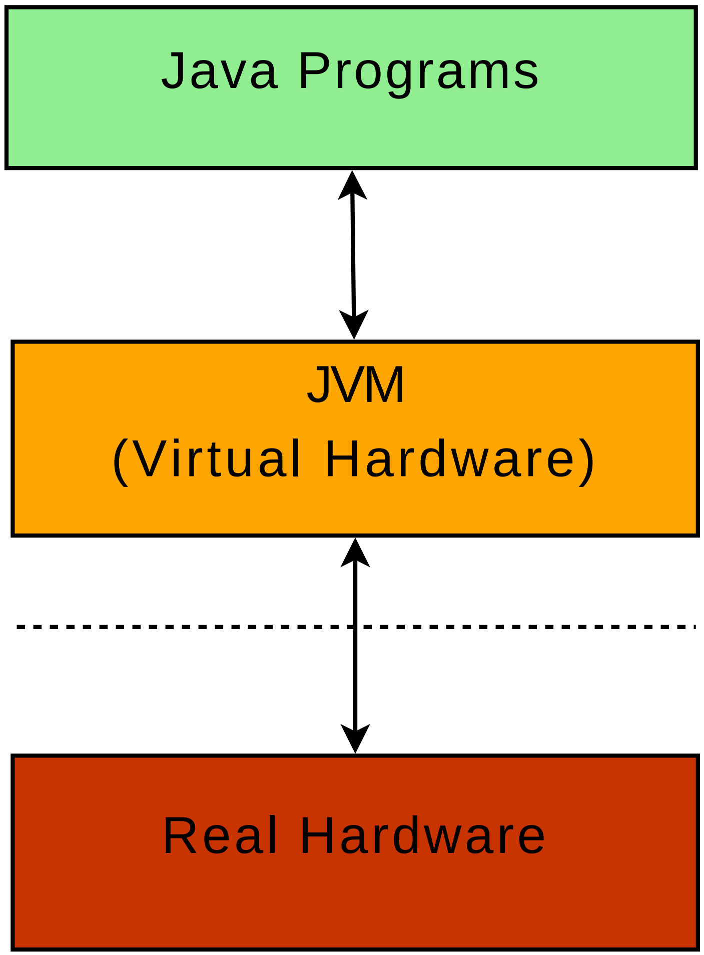

Motivation

Hardware Impact

- The impact of hardware on program behaviour can be significant
- Strong correlation exists: hardware performance $\leftrightarrow$ program behaviour

Hardware Event Counters

- Hardware counters widely exist in modern processors
- Accessible from software libs: **PAPI**, PMAPI,PCL,...

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Use hardware event data to improve adaptive optimizations in JVM

Program Phases

There are different types of program phases

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Flat Phases

refer to the contiguous intervals where show a stable, flat performance on a type of sampled, profiling data

Periodic Phases

long term repetitions in execution, showing unstable performance but sharing similar patterns

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Periodic Phases

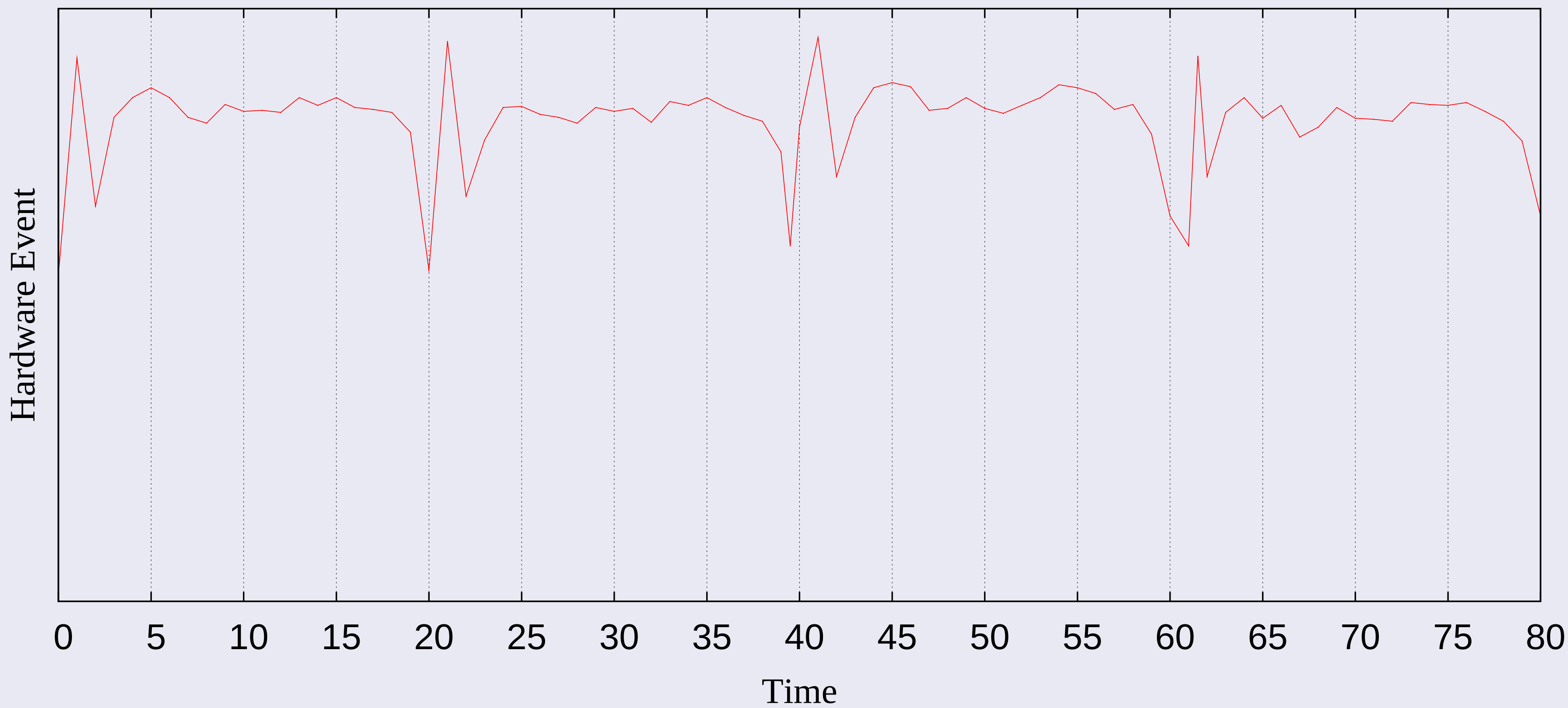
long term repetitions in execution, showing unstable performance but sharing similar patterns

Detect this long term **periodic phases** from hardware data and employ the phase information in adaptive optimizations

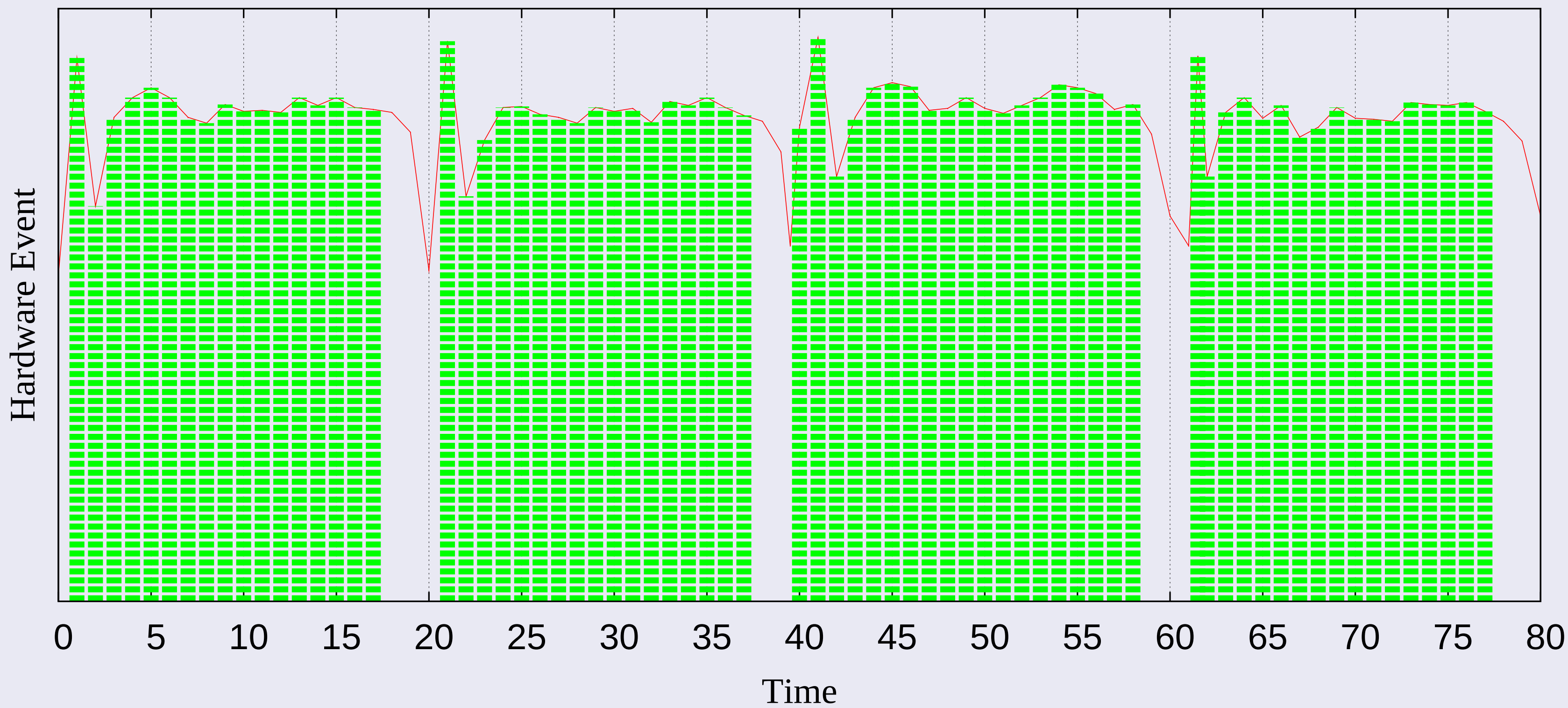
Contributions

- Highlight the hardware impact on Java program execution
- Develop online **pattern** creation algorithm to represent hardware event
- Detect long term periodic **phases** from hardware patterns
- Implement an **adaptive recomplication strategy** using phase information

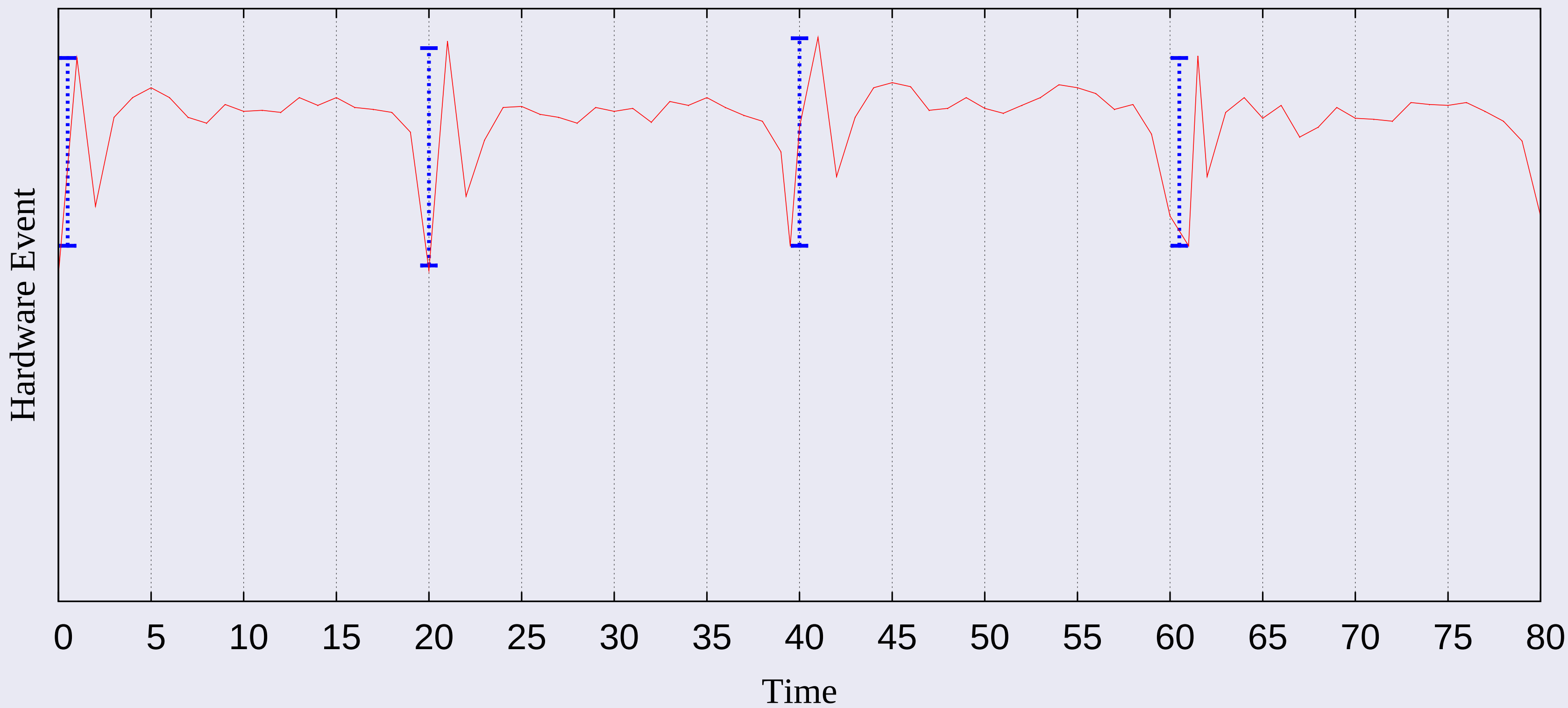
Hardware Event Data Example



Recurrent Phases



Hardware Pattern



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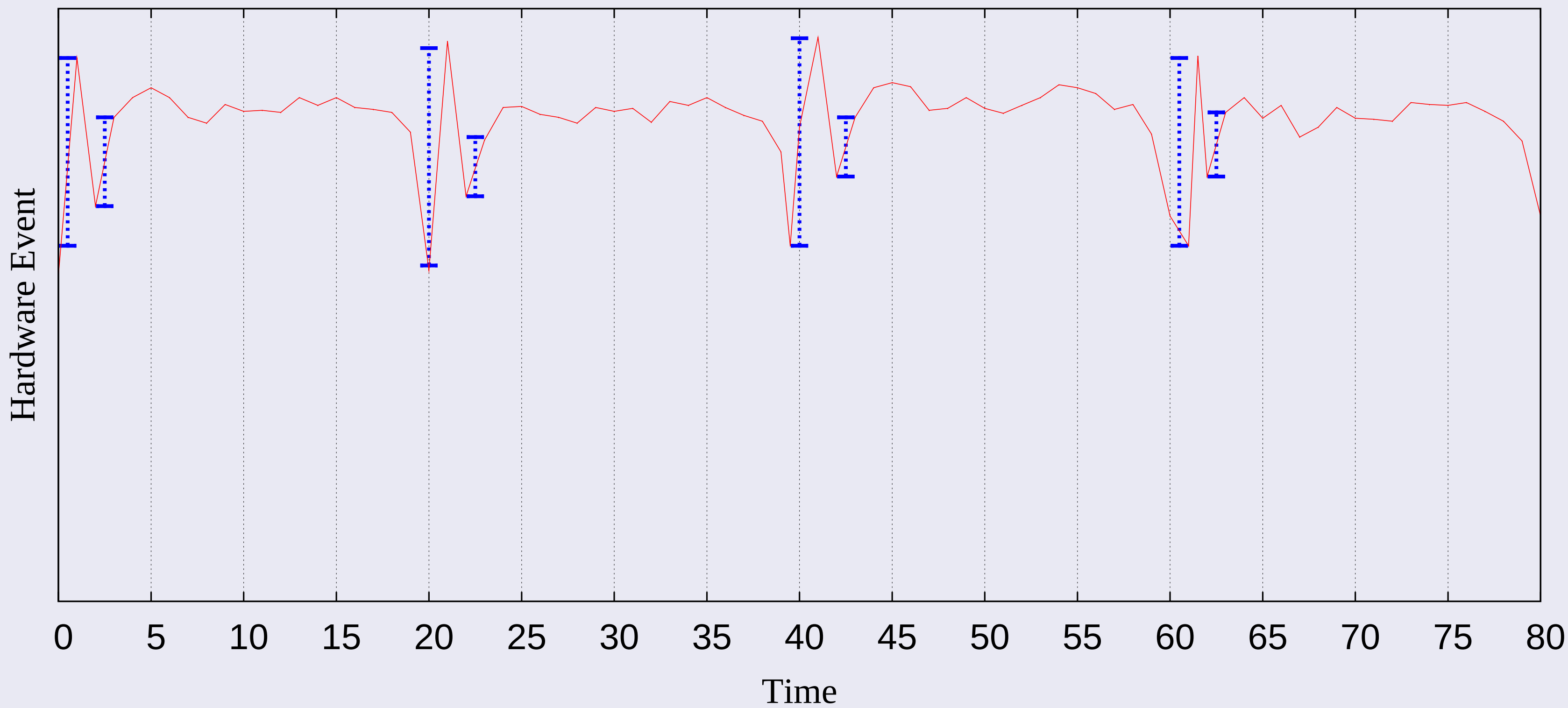

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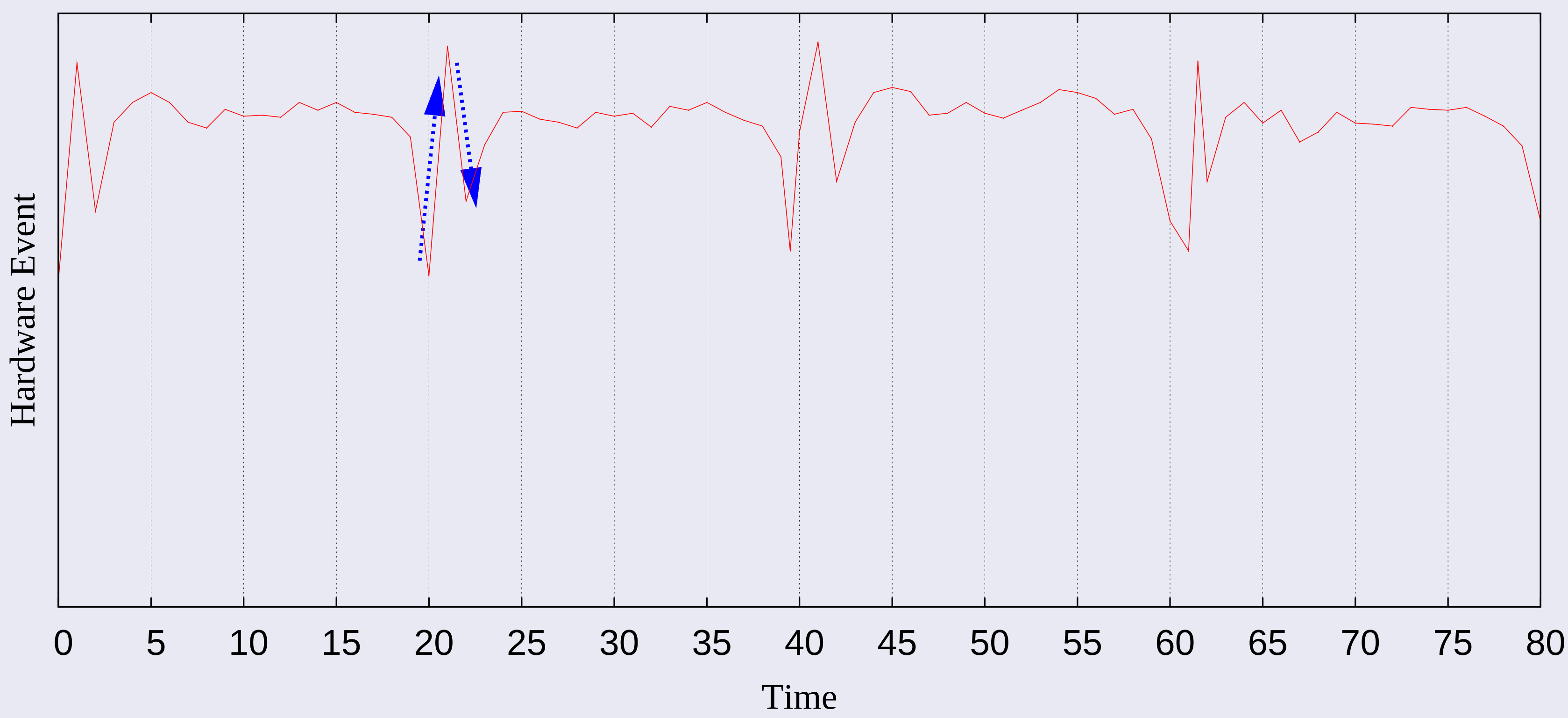

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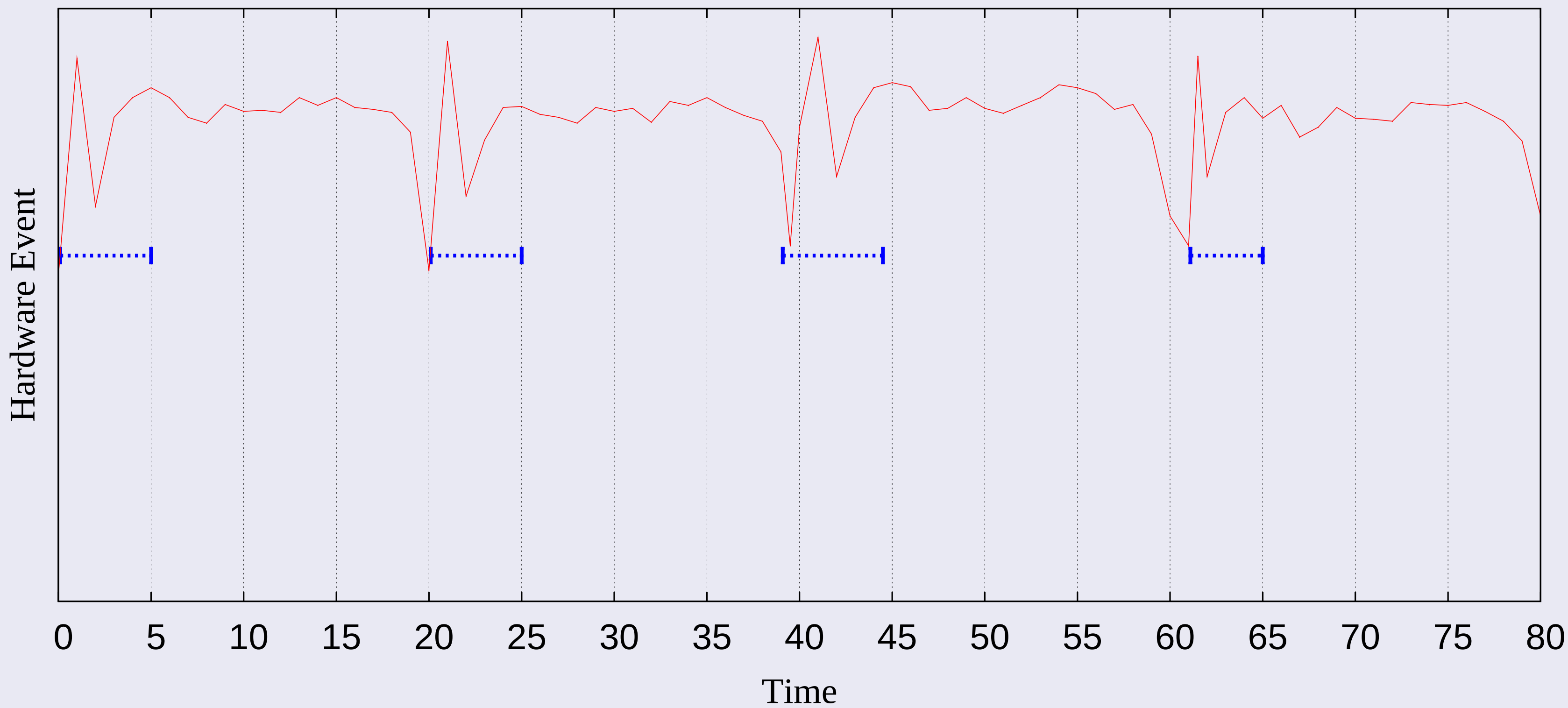

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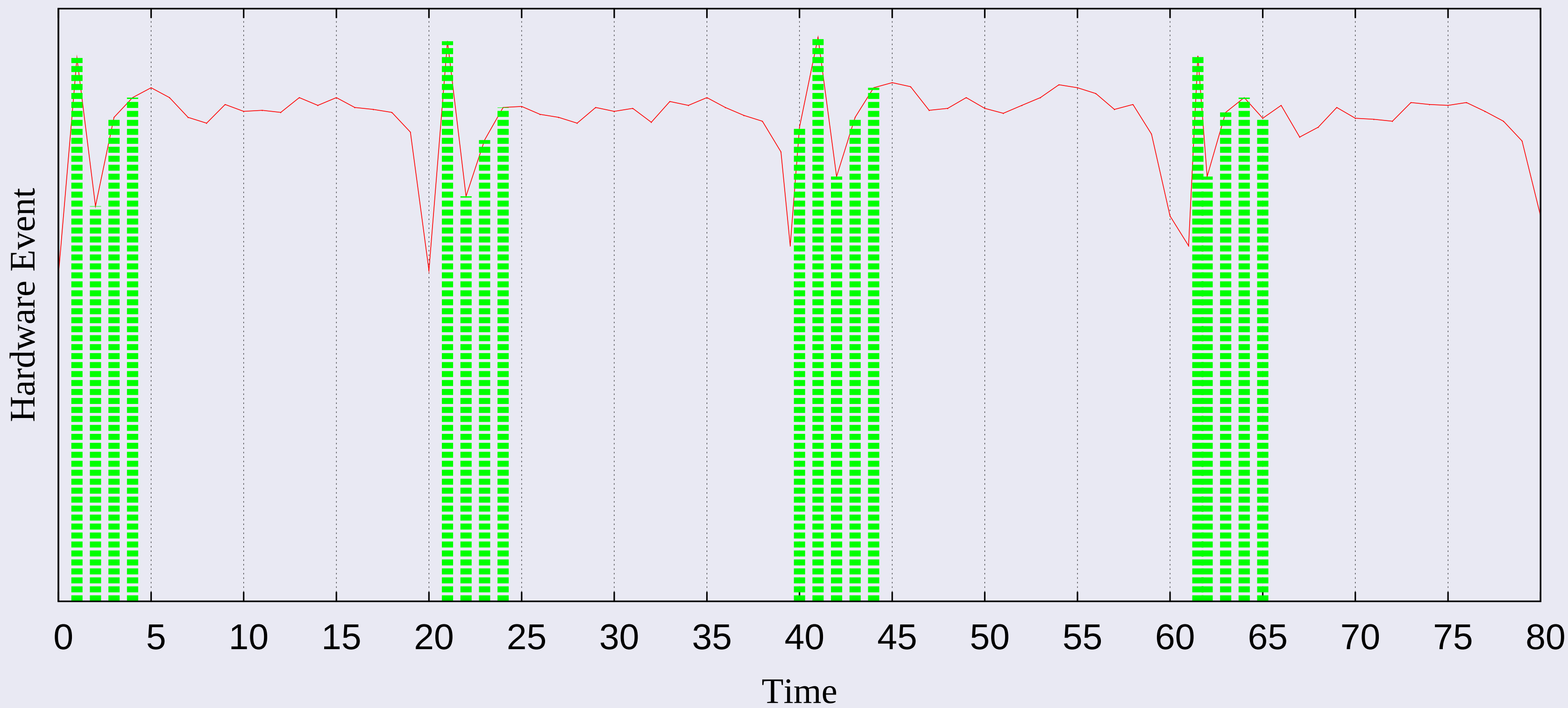

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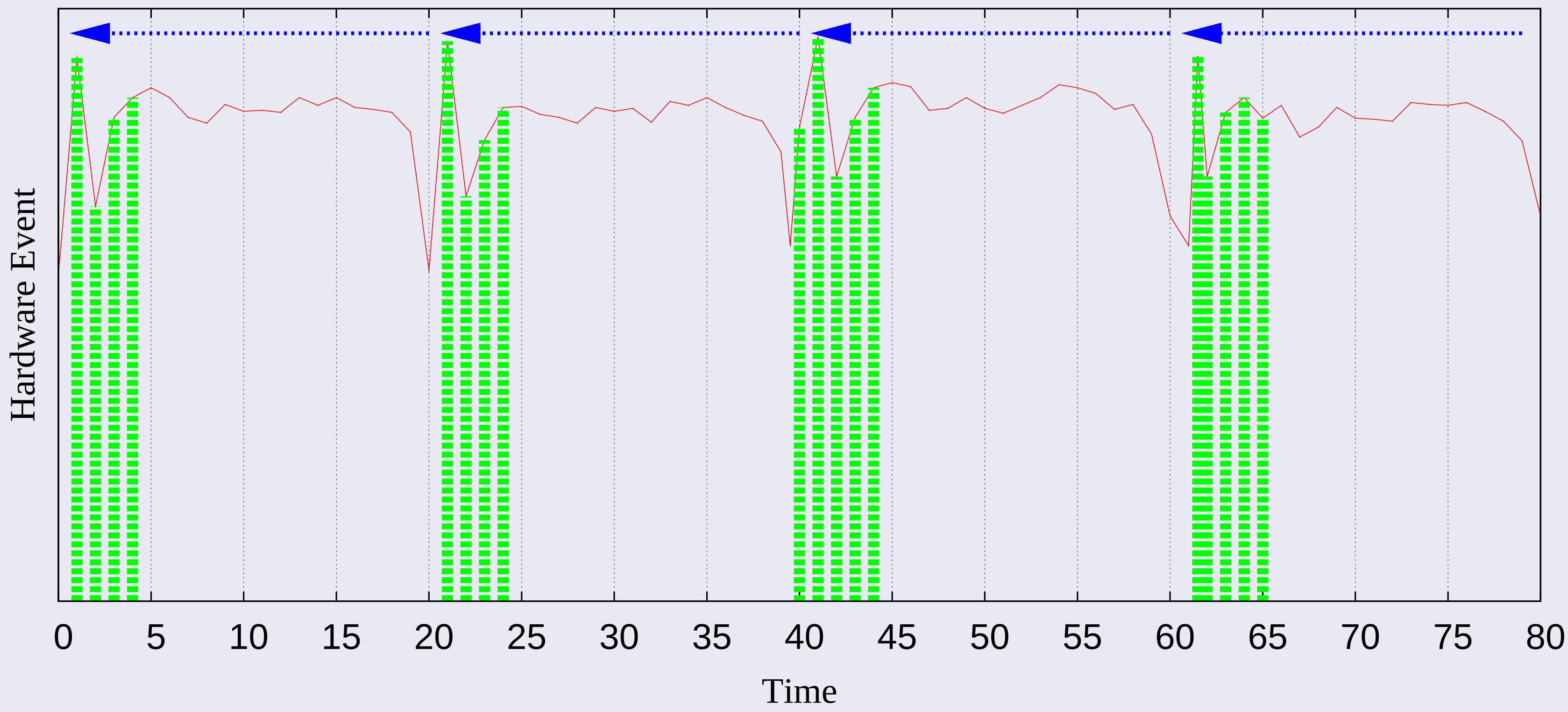
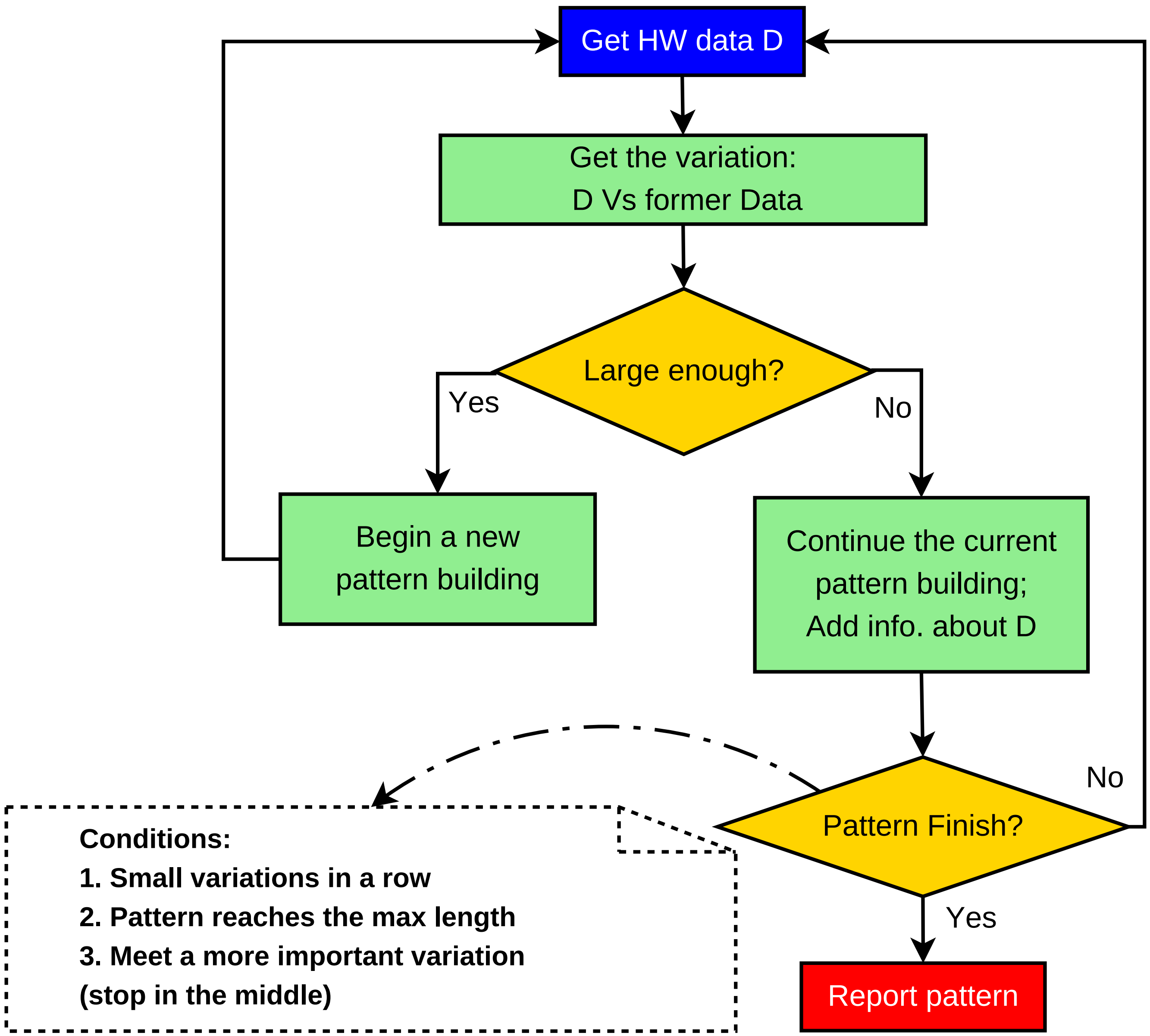


Pattern Building Algorithm (Simplified)



Pattern Building Example

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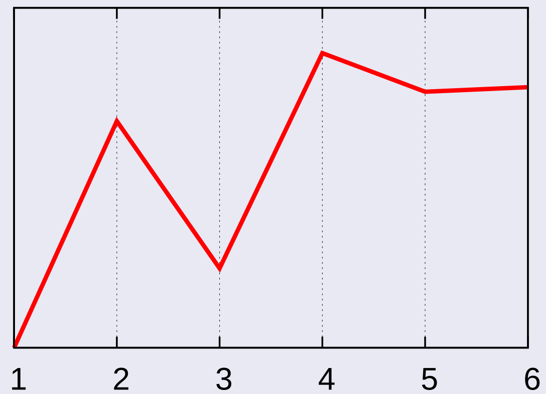

Pattern Building Example

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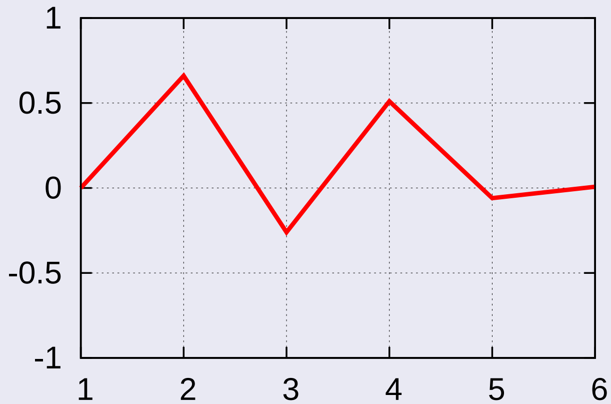
(2) Variation



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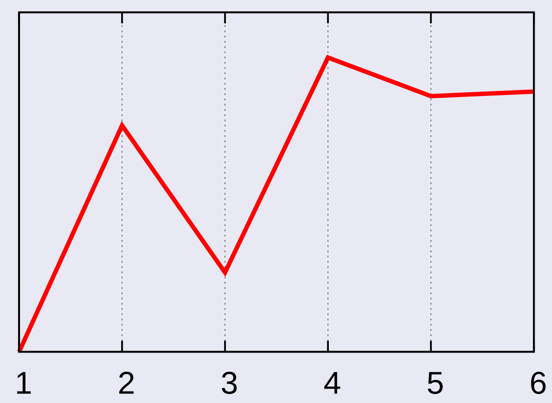
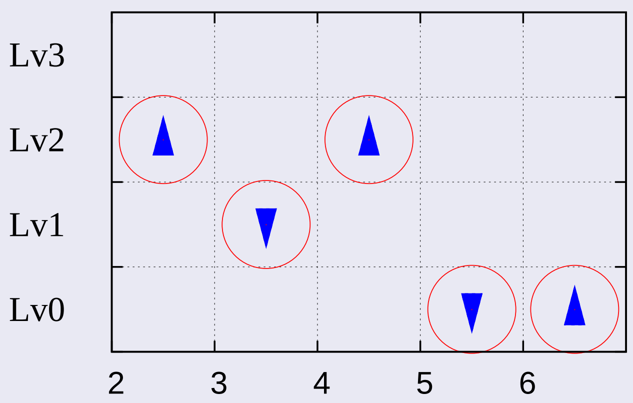


(3) Level



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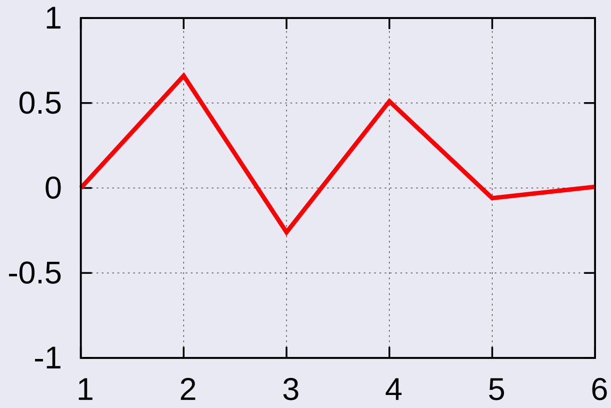

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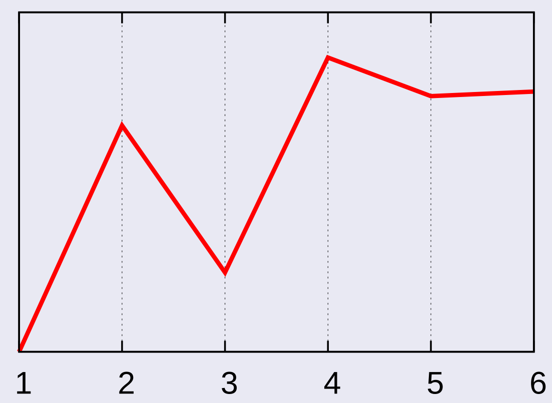

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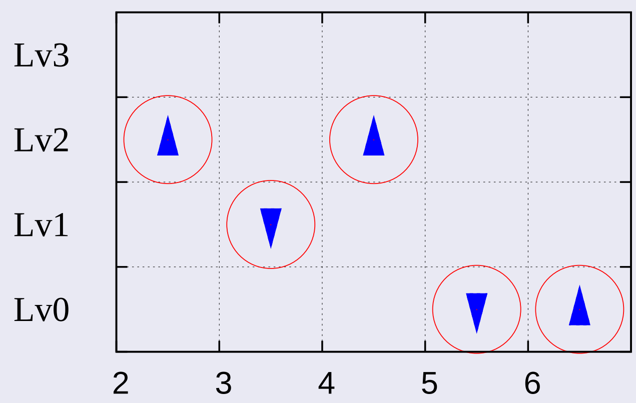

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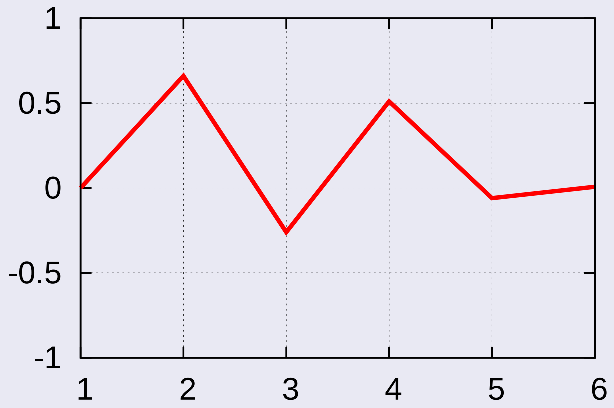
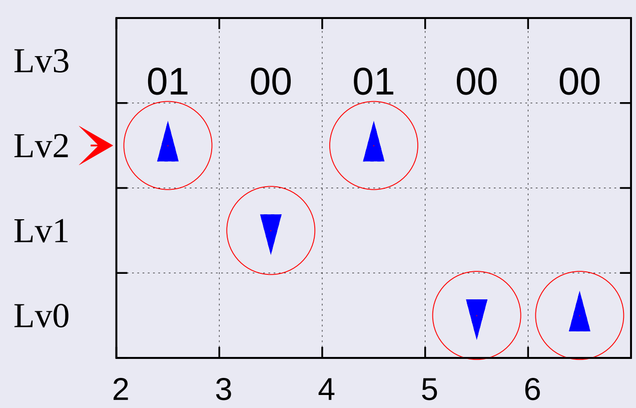


(4) Pattern

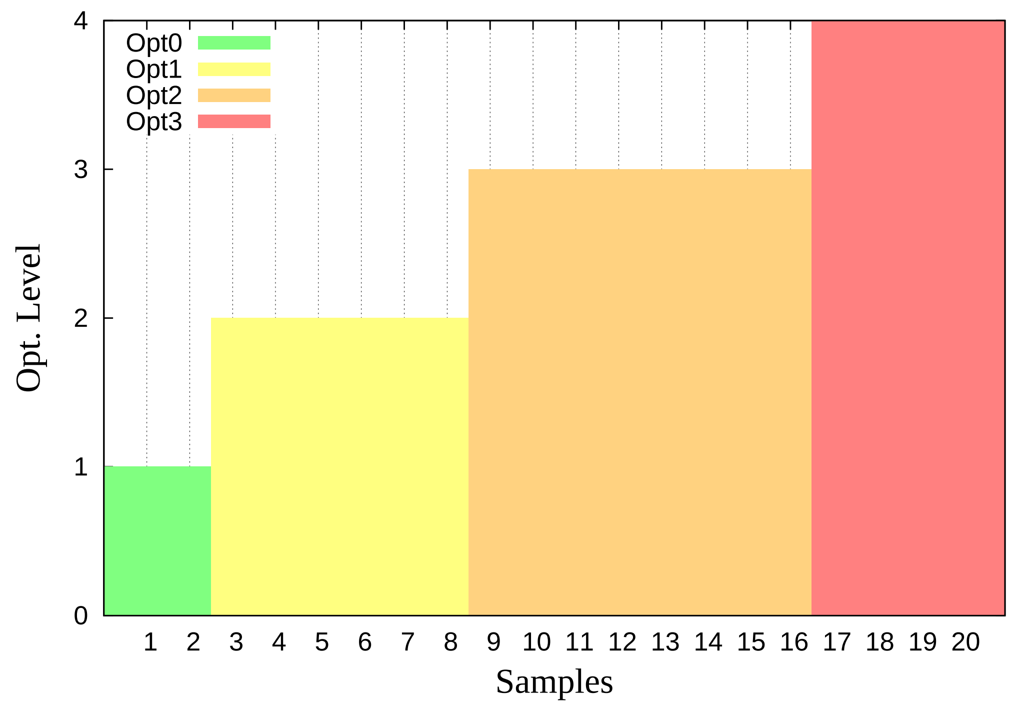


Pattern Analysis

- Patterns are stored and analyzed
- The number of occurrences determines the **hotness** of a pattern
- The hottest pattern is used to represent the current program **phase**
- The **phase information** is used to archieve a better adaptive hot method recompilation strategy in Jikes RVM

Recompilation in Jikes RVM

- Get method samples
- Compute the *Past* time in a method
- Estimate the compilation cost C_i to optimization level i



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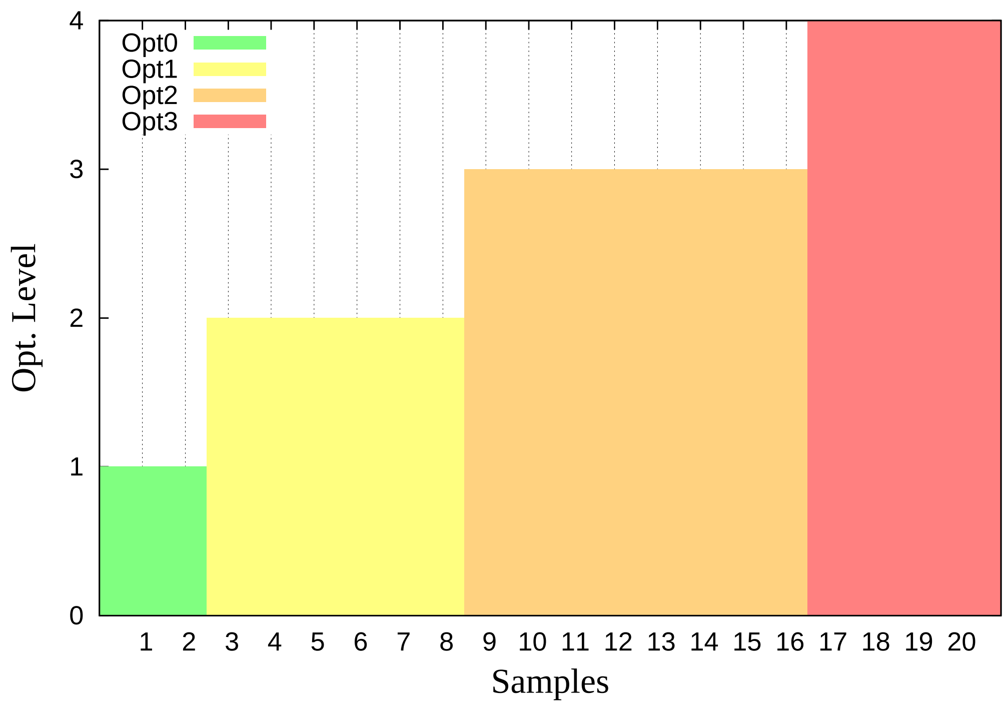

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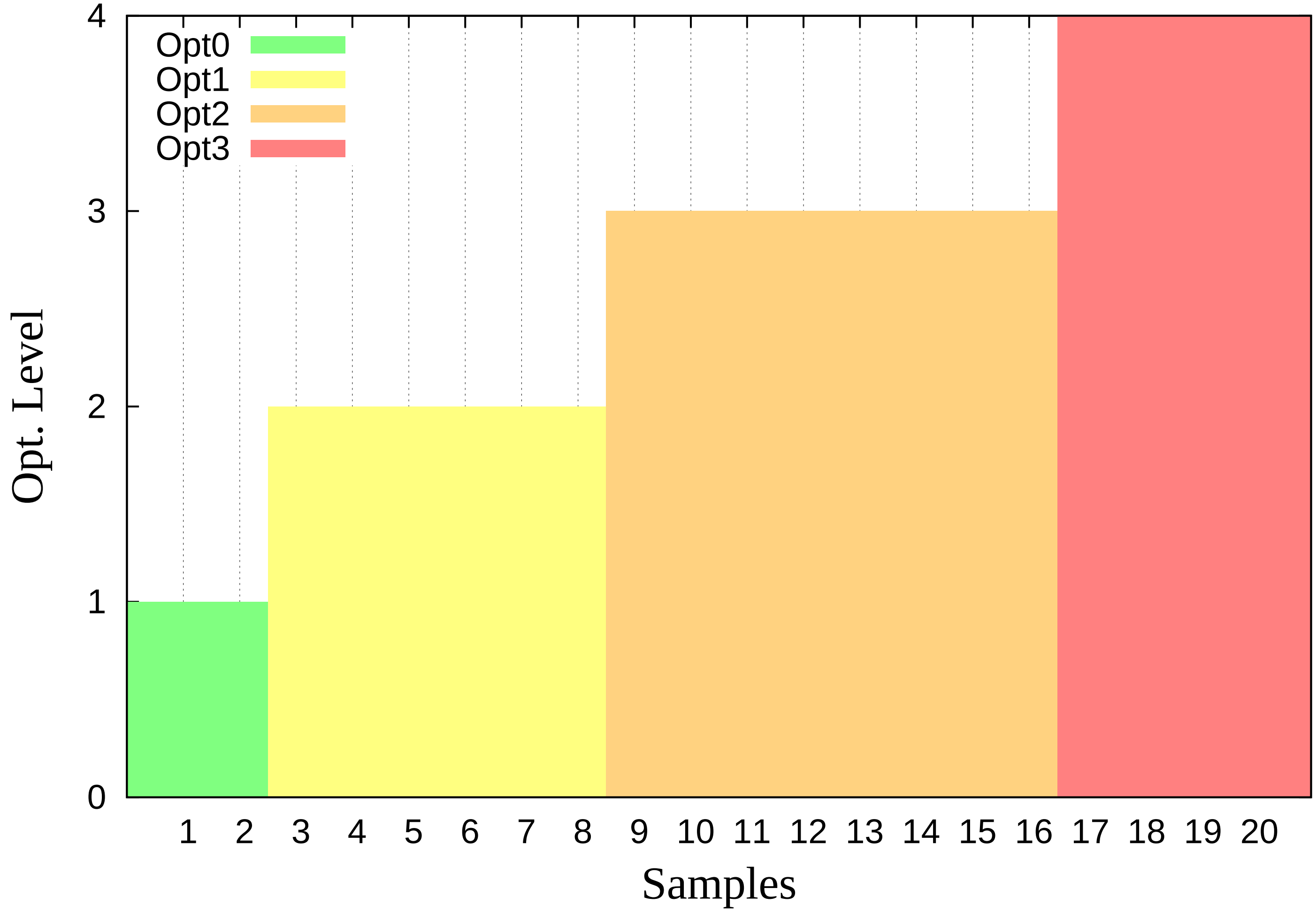
Assume $Future \equiv Past$

Optimization Opportunity



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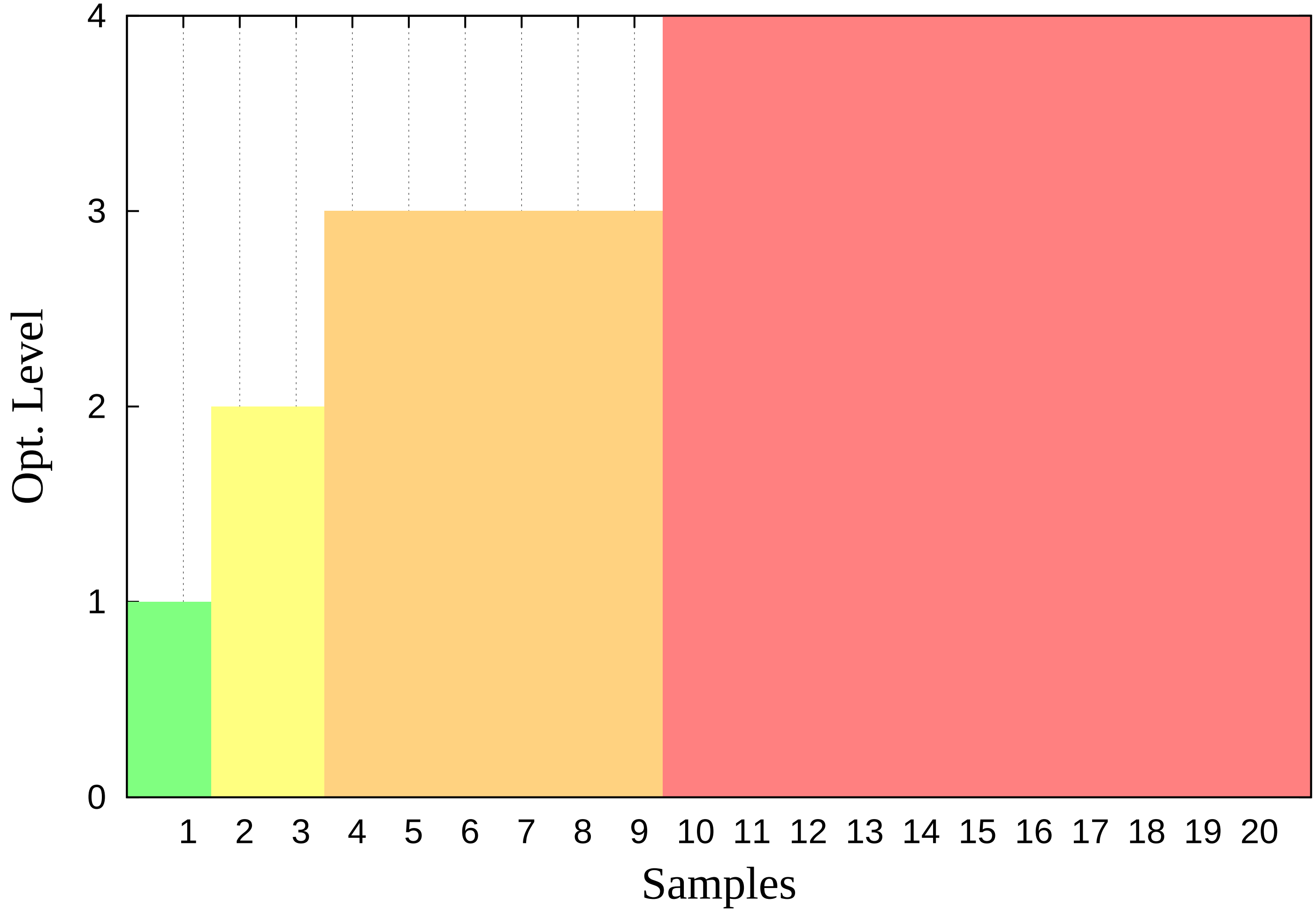

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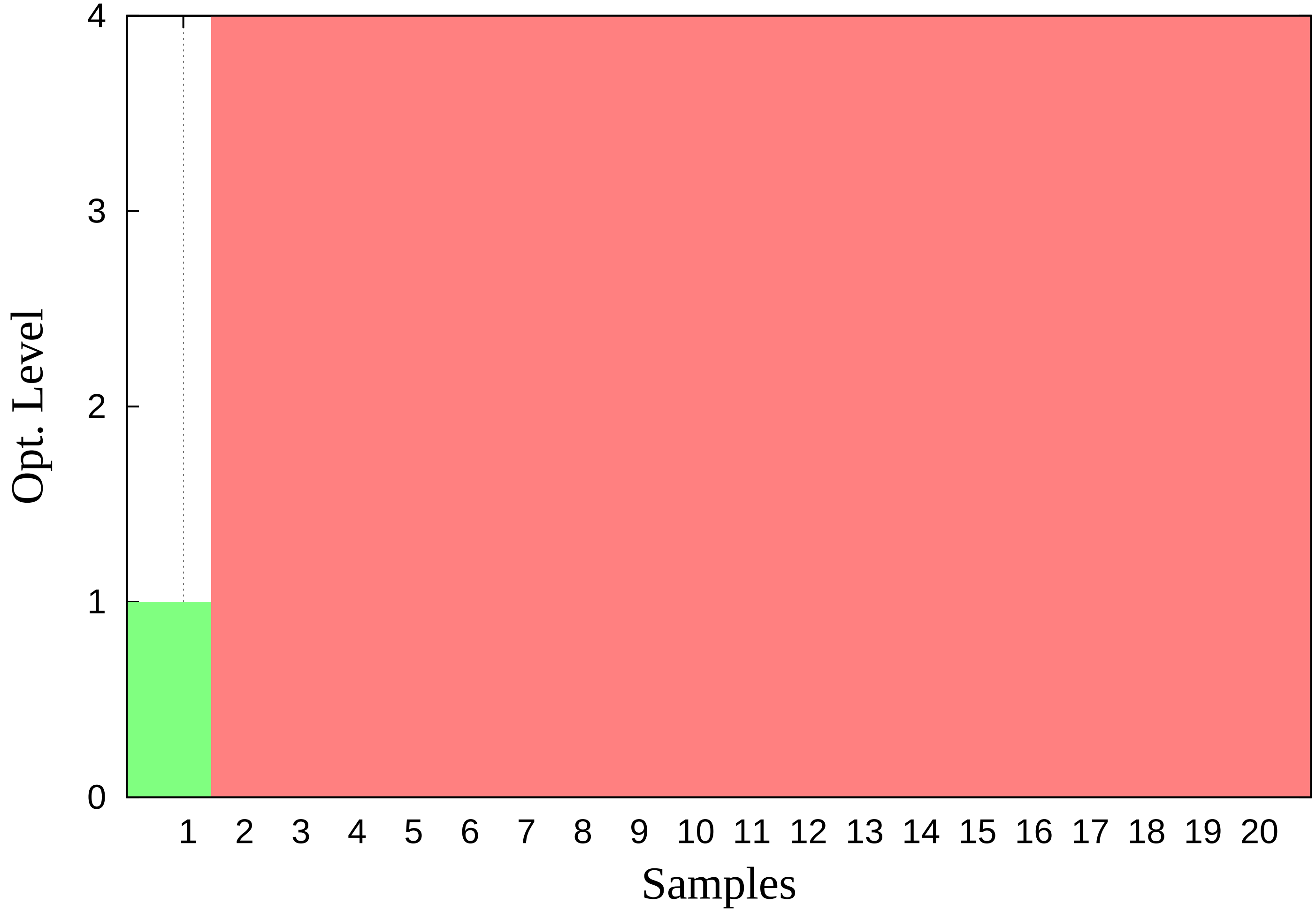

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Program State	Sampled Methods	Hardware Event Behaviour	Recompilation Aggressiveness
New	The "Beginners"	No recurrence of patterns	Low
Young	Important methods	Recurrences of patterns	High
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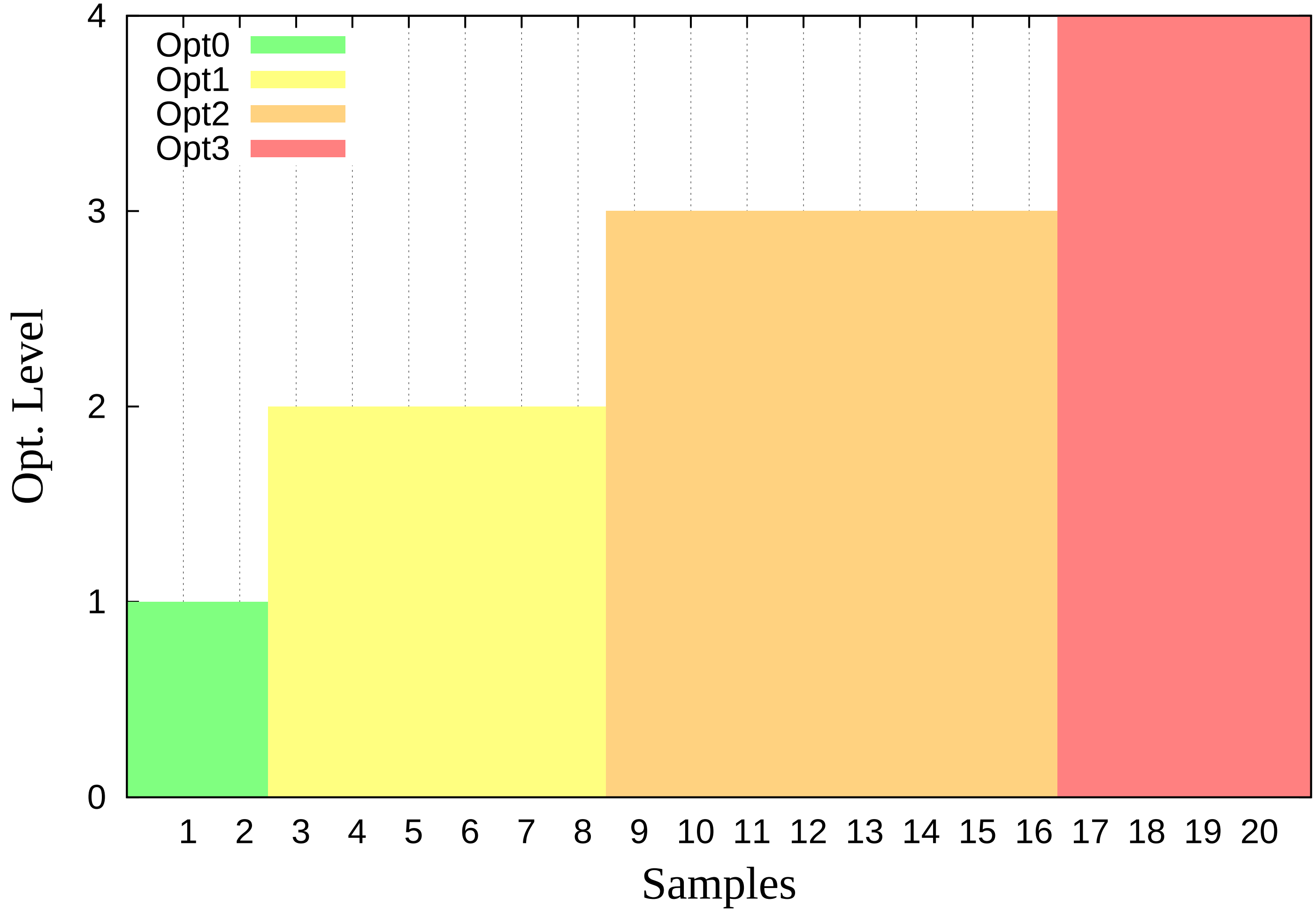
- *Future $\neq$ Past*
    - Fixed aggressiveness $\Rightarrow$ Adaptive aggressiveness

Optimization Opportunity

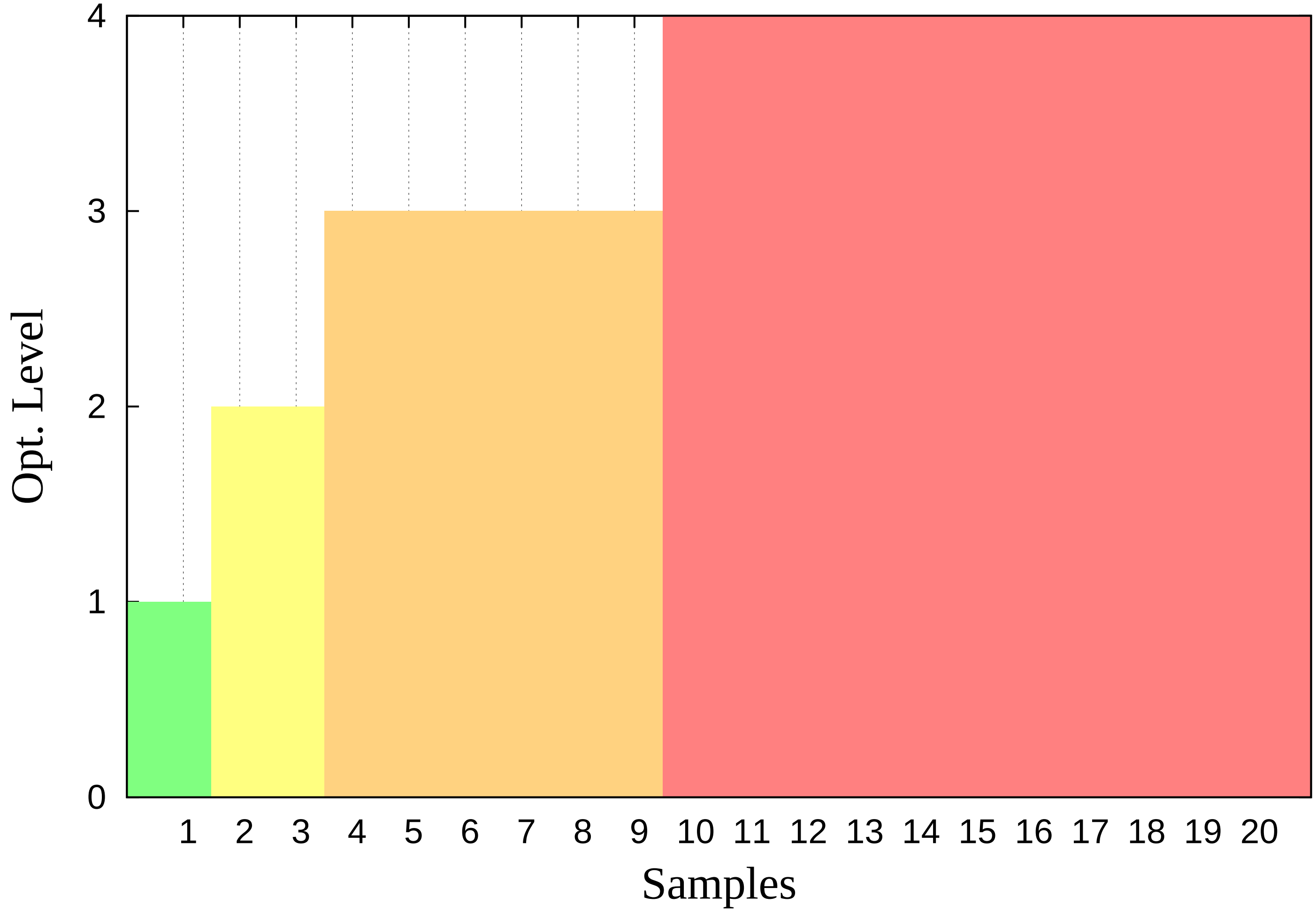
- Optimize code to higher levels earlier
- Possibly save recompilation overhead for intermediate levels
- Save unnecessary recompilation for the "beginners"

Original

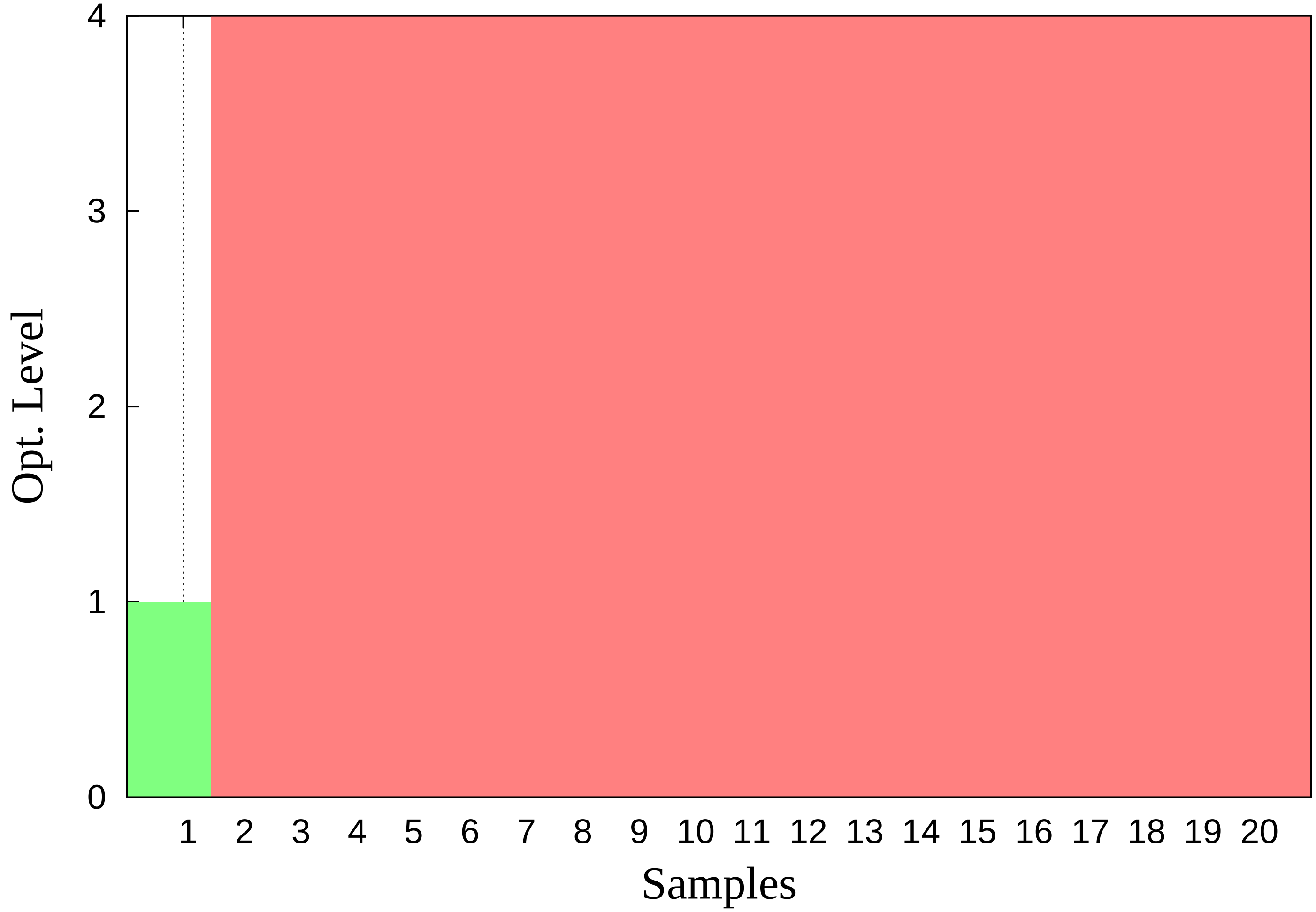


Opt0
Opt1
Opt2
Opt3
Opt. Level
Samples
0
1
2
3
4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Online Optimization



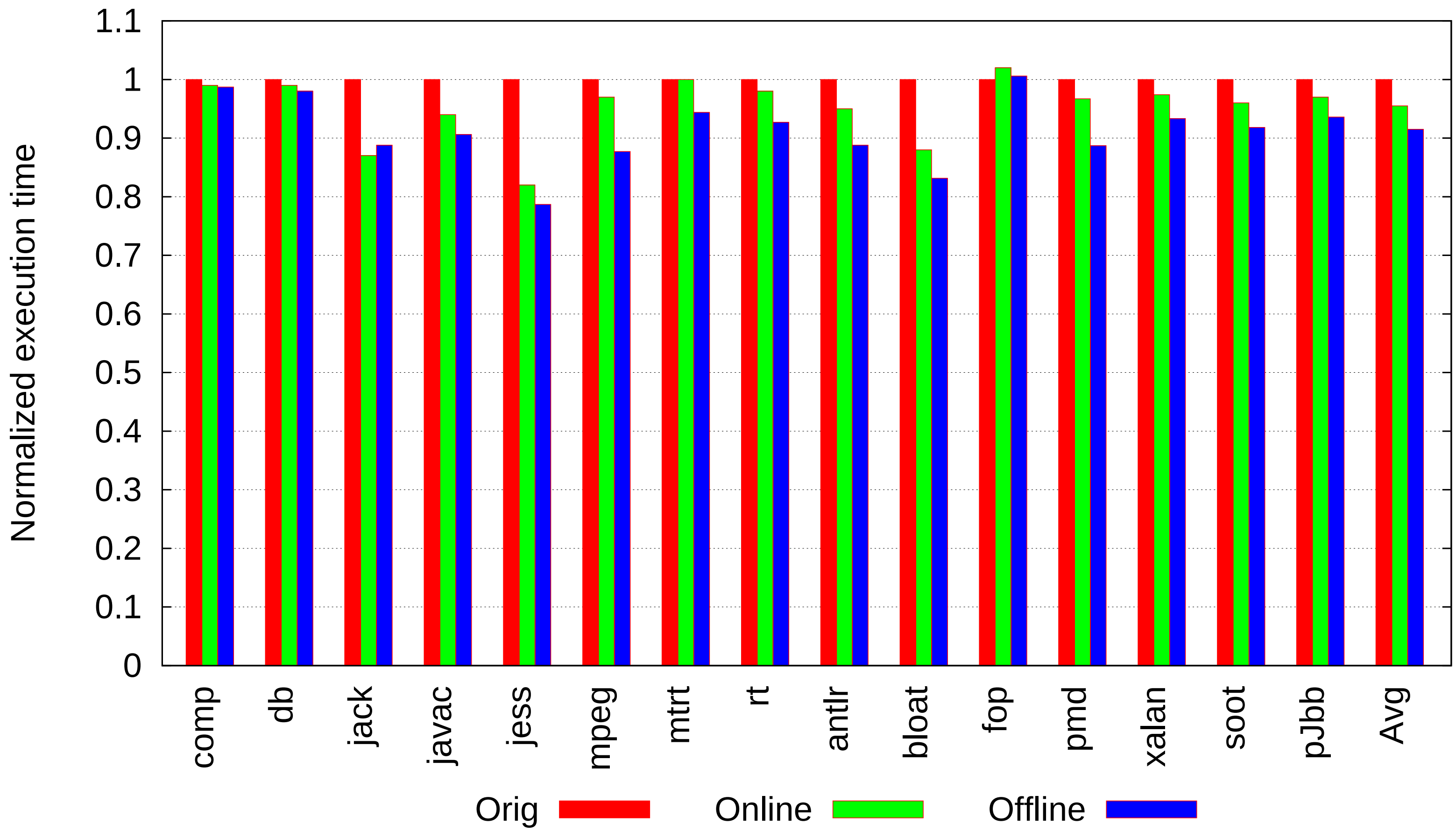
Offline Head Space Study



Experimental Set-up

- Benchmarks:
  - SPECjvm98 suite
  - Dacapo benchmarks: antlr, bloat, fop, pmd, xalan
  - Soot and PseudoJbb
- Test on Athlon 1.4G, 1GB memory, Debian Linux kernel 2.6.9
- Average of the middle 11 in 15 runs

Recompilation Results



Whole Execution Time Reduction (incl. all overhead)		Average	Up to
Offline	Use training runs	**8.7%**	**21%**
Online	Use HW pattern info.	**4.4%**	**18%**

Whole Overhead

Benchmark	Overhead (%)	Benchmark	Overhead (%)
compress	2.02	antlr	2.12
db	1.39	bloat	1.65
jack	1.71	fop	1.69
javac	1.13	pmd	1.70
jess	0.49	xalan	1.07
mpegaudio	1.76	soot	1.85
mtrt	0.82	PseudoJbb	0.77
raytrace	1.30	**Average**	**1.43**

- The "overhead" includes all sources from hardware monitoring, pattern construction, information analysis, and building control events to adaptive engine

Conclusions

- Understanding repetitive program behaviour and exploring phases in program execution is important
- We implemented a technique for determining program phases from hardware data
- We applied the phase information in adaptive recomplication
- Hardware information can be used in a wide range of areas
  - Runtime profiling, selecting GC points
  - Program understanding, system reconfiguration, instruction/data relocation and prefetch ...

Future Work

- Test other hardware events/combinations
- Use offline analysis results for repeatable executions
- Attach hardware variation with software structures
- Advanced static analysis can be helpful
- Develop other adaptive applications

Thank you!

Questions?