CLIPPER: Counter-based Low Impact Processor Power Estimation at Run-time

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Outline

- Motivation
- Methodology
- Results
- Example Application
- Summary

Motivation

103.3 mJ | 116.9mJ | 134.9mJ

↑ **50 % Compression** ↑

90.4 mJ | 95.1 mJ | 106.9 mJ

↑ **90 % Compression** ↑

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Motivation

- Conserving power and energy has become a major design problem for portable devices
- Knowledge of run-time power/energy data allows clever decisions to be made
- Any optimization system requires overheads. These must not outweigh the benefits.

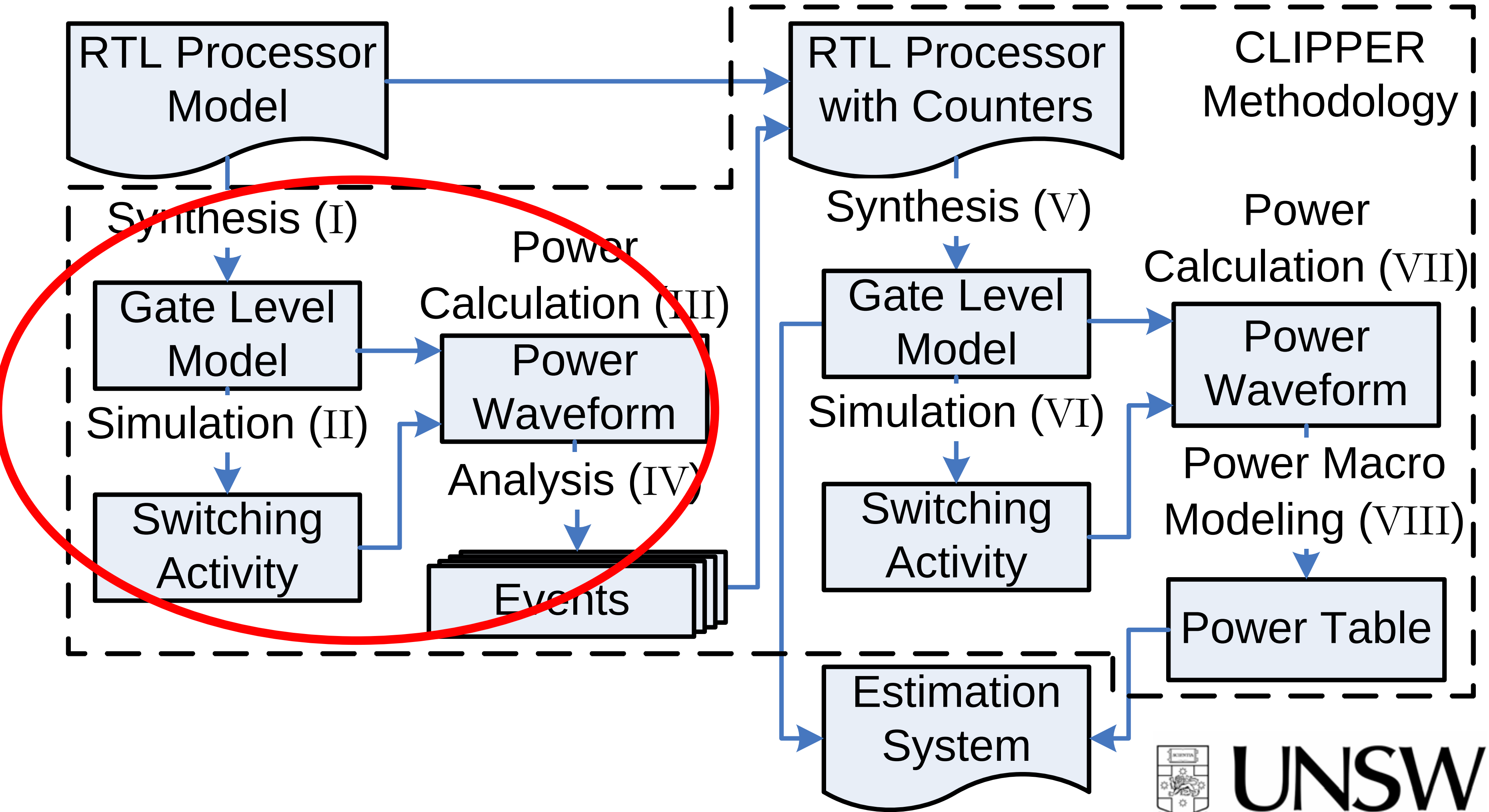
Problem

- Problem
  - Run-time feedback of power/energy required
  - Power measurement is either not frequent enough or costs too much energy
- Solution
  - Estimate power consumption in parallel to execution
  - Use small counters to minimize impact

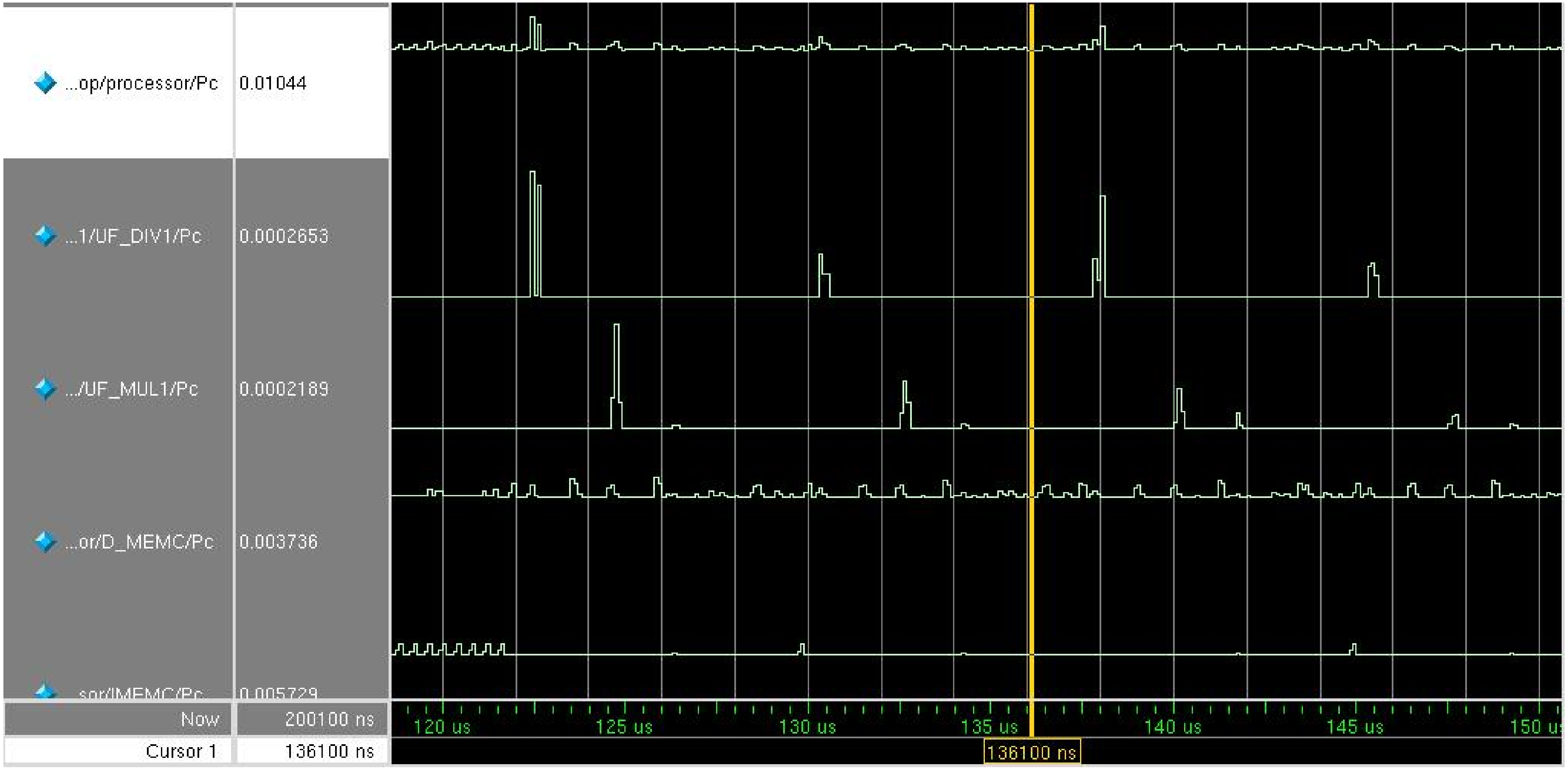
CLIPPER Methodology

- Model power of system
- Detect events that contribute to power consumption
- Add event counters to tally event occurrence
- Produce macro-model of system via regression analysis
- Modify software to read counters

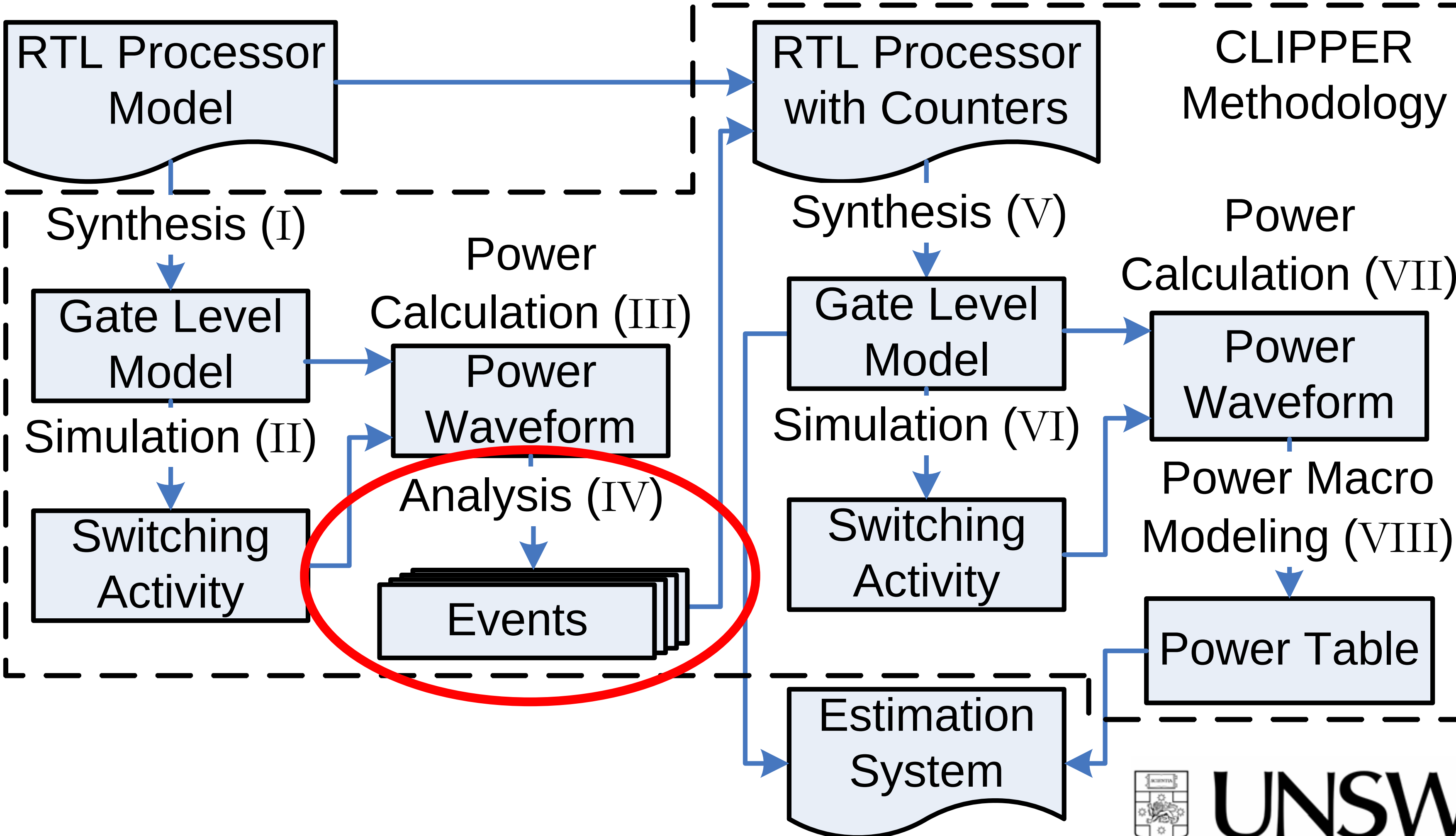
CLIPPER Methodology



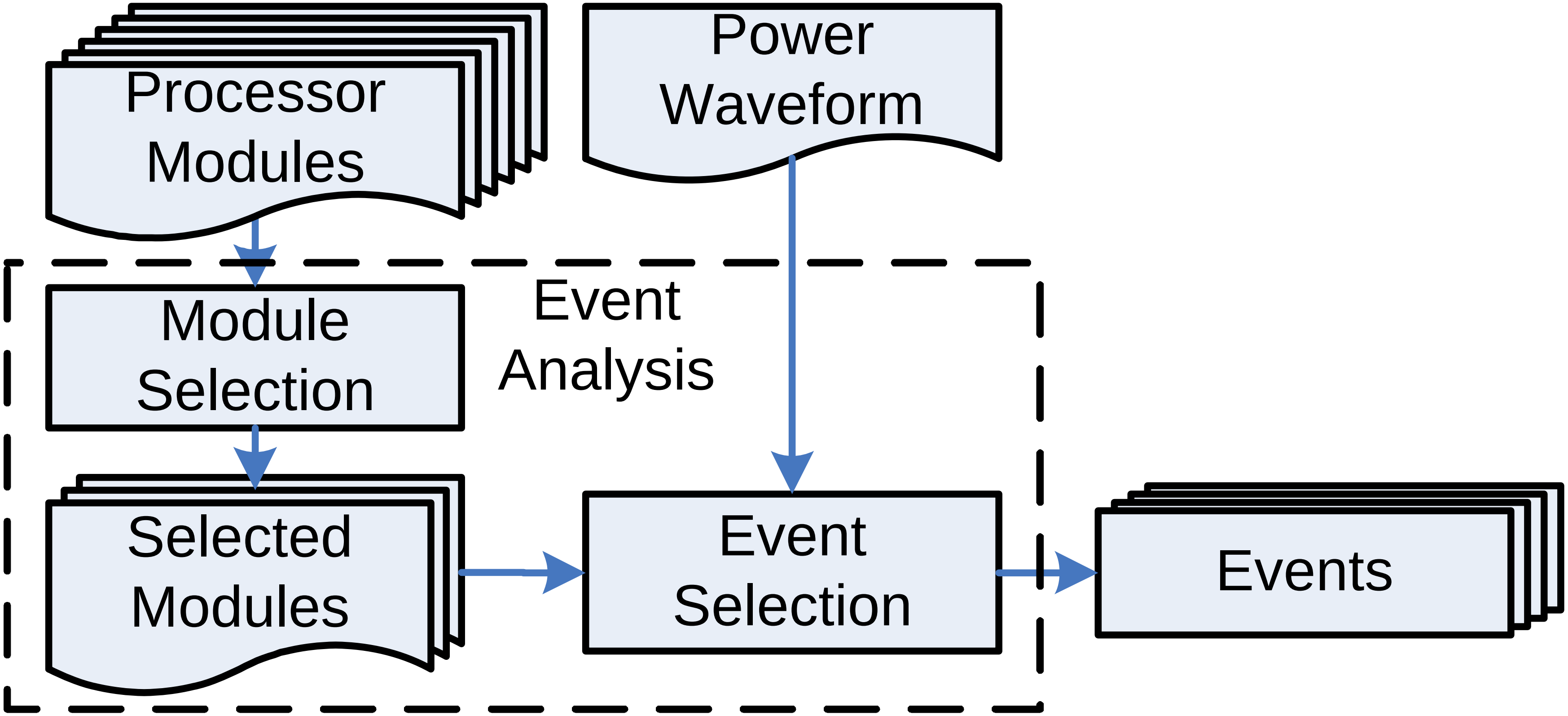
Power Simulation



CLIPPER Methodology



Event Analysis



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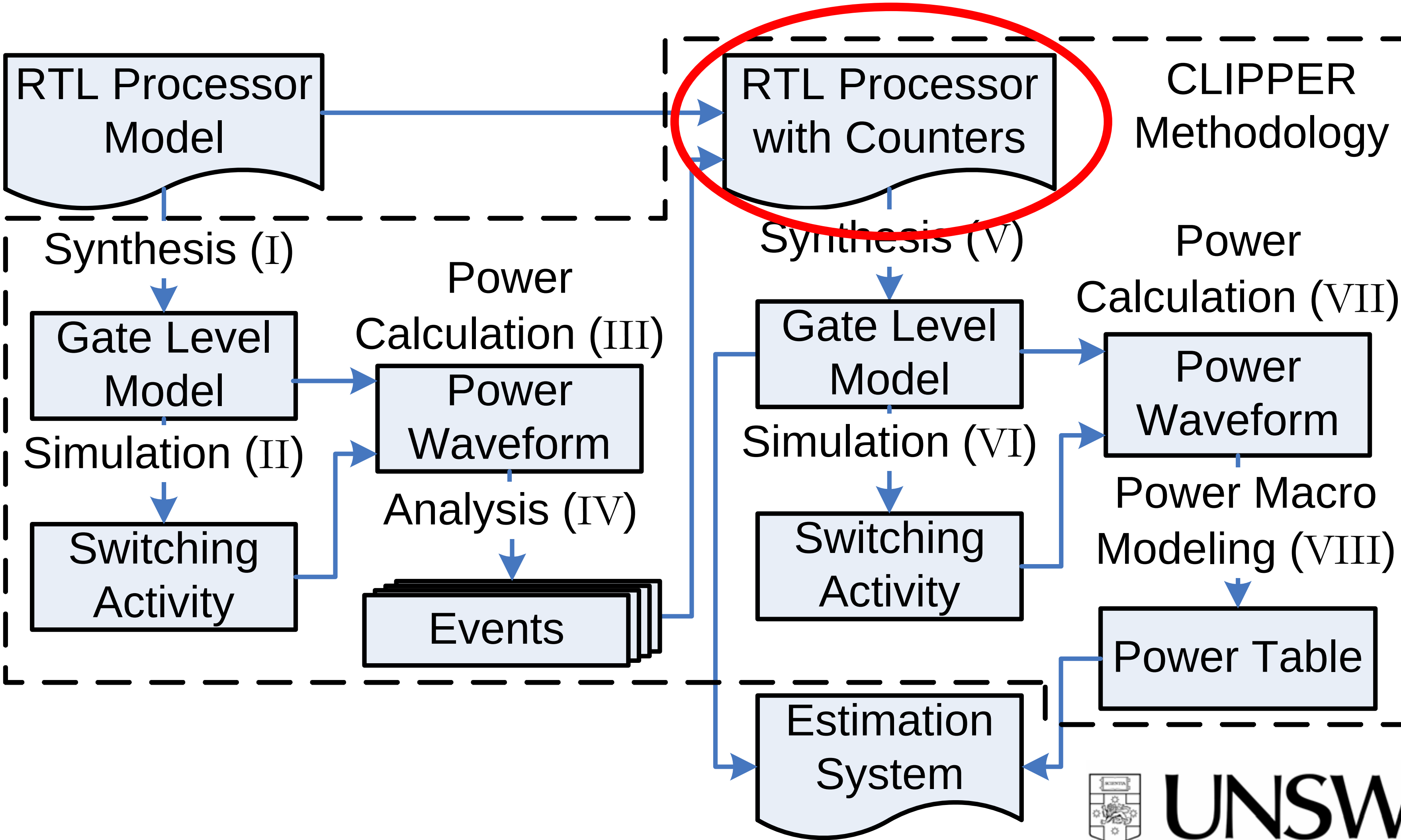
Finding Events

- Events are detected by states of one or more control signals
- Most events are easily determined. E.g:
  - Cache misses
  - Major operations (divide, flops, etc.)
  - Peripheral access

Finding Events

- For each significant power change in trace
  - Find signals that change at the same time
  - If signals correlate with power throughout trace, add it to an event
- For each event
  - Remove covered signals in the set
- For each pair of events
  - Remove duplicates

CLIPPER Methodology



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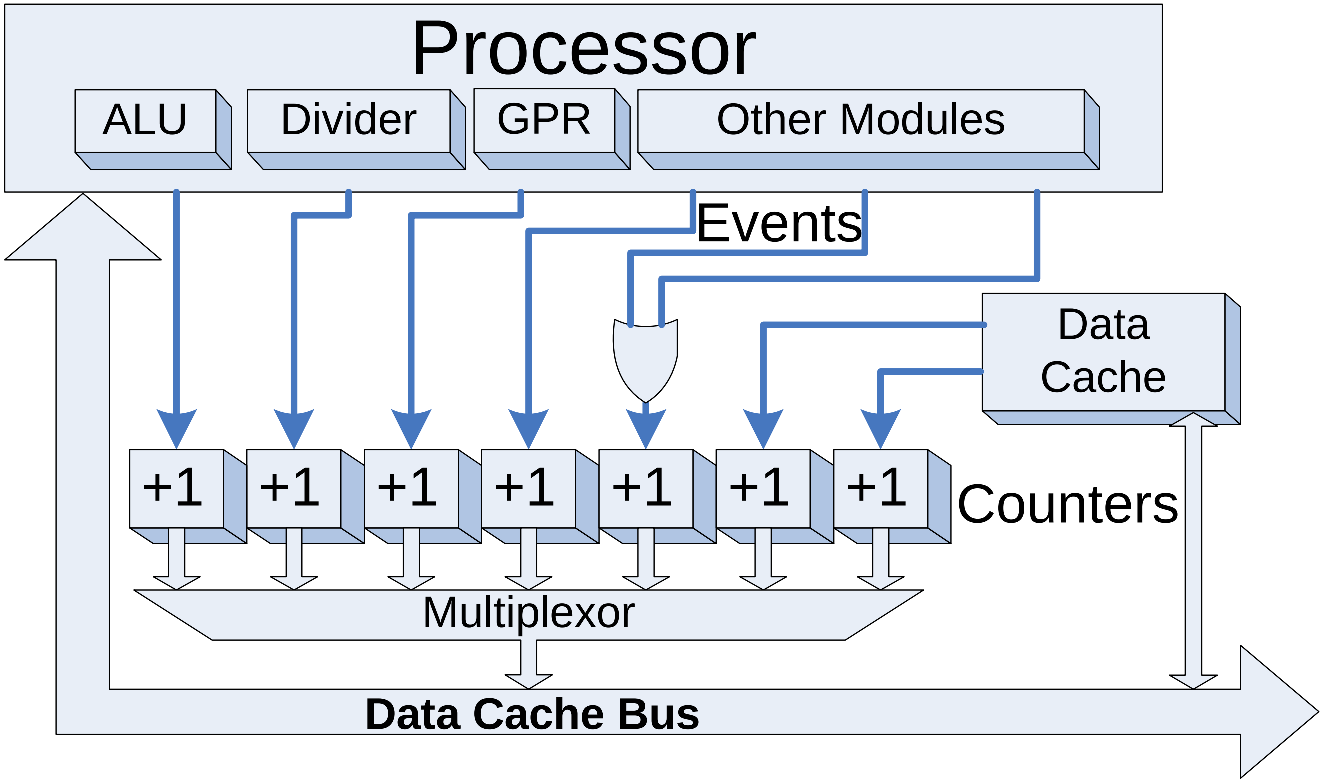
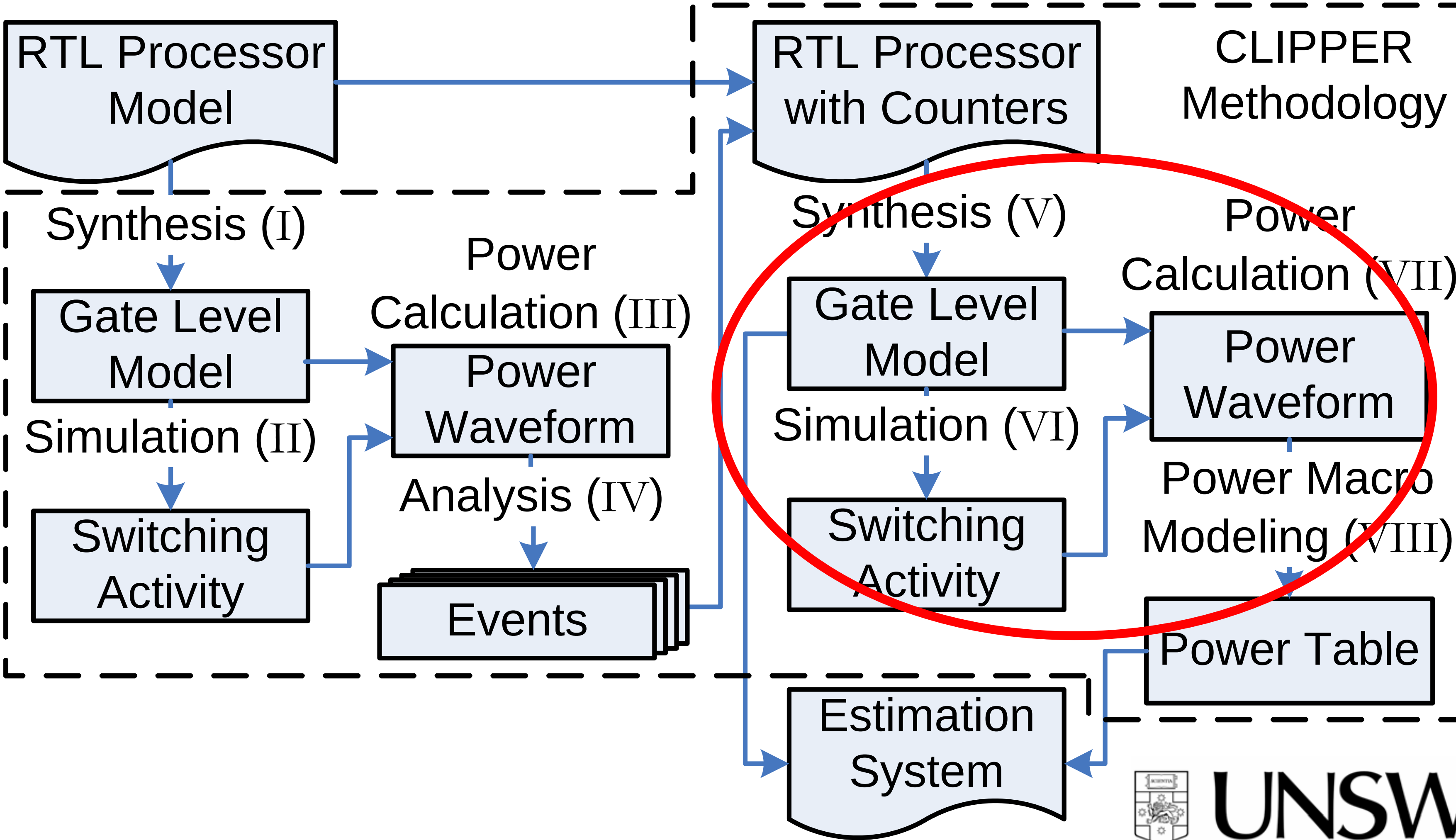
CLIPPER Counters



CLIPPER Methodology



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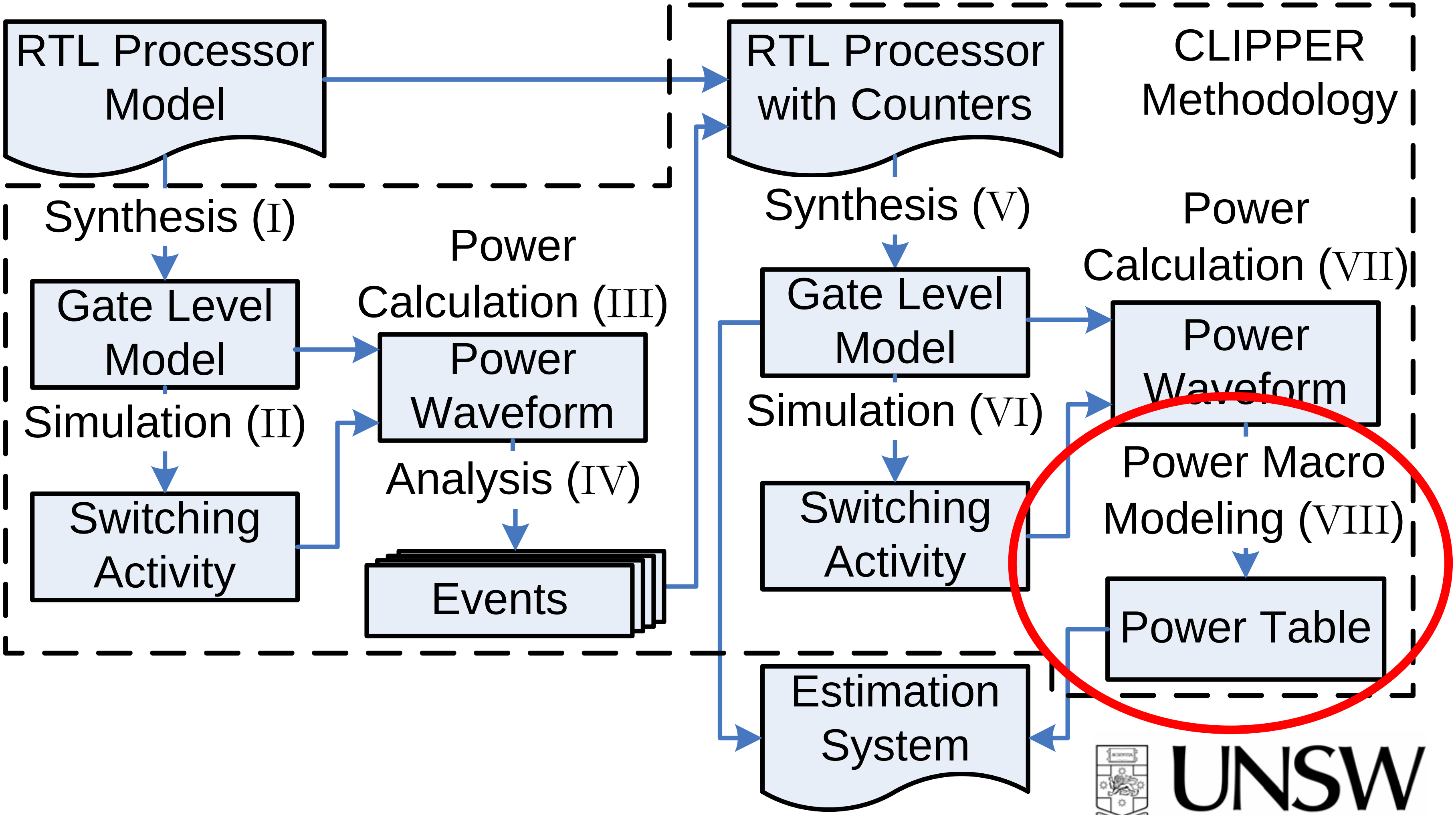
CLIPPER Methodology



Power Table

Event	Power Contribution
Base (Static + Constant Dynamic Power)	57
Divide	460
Multiply	9
Register File Write	17
Dcache Miss	198
…	

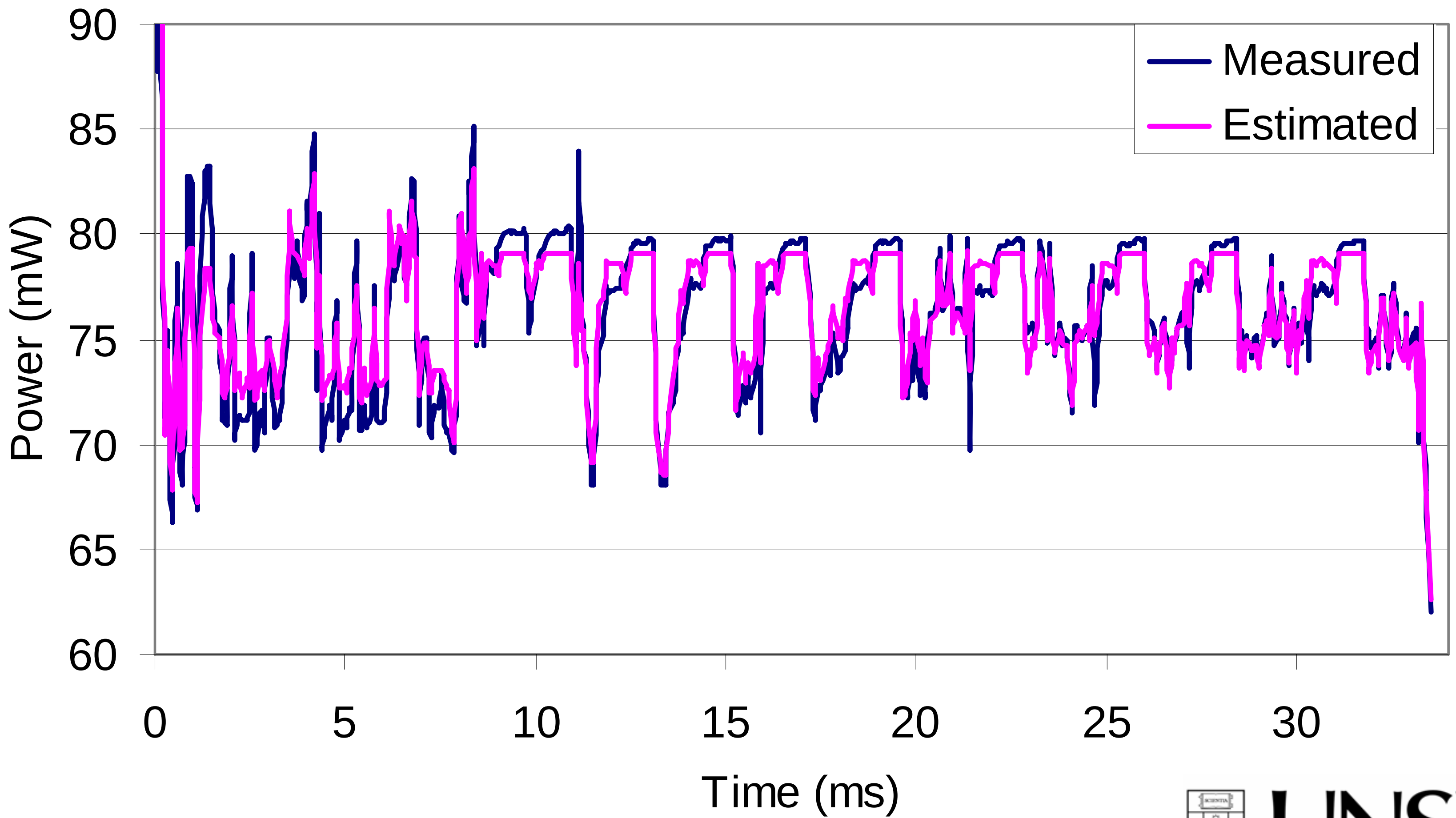
Implementation

- Implementation of SimpleScalar processor with the integer PISA instruction set created with ASIPMeister
- On-chip instruction and data cache
- Synthesized in Synopsys Design Compiler in 180nm process with 125Mhz clock speed
- 9 events detected (divide, multiply, icache miss, dcache miss, dcache w/b, register change etc.)

Impact

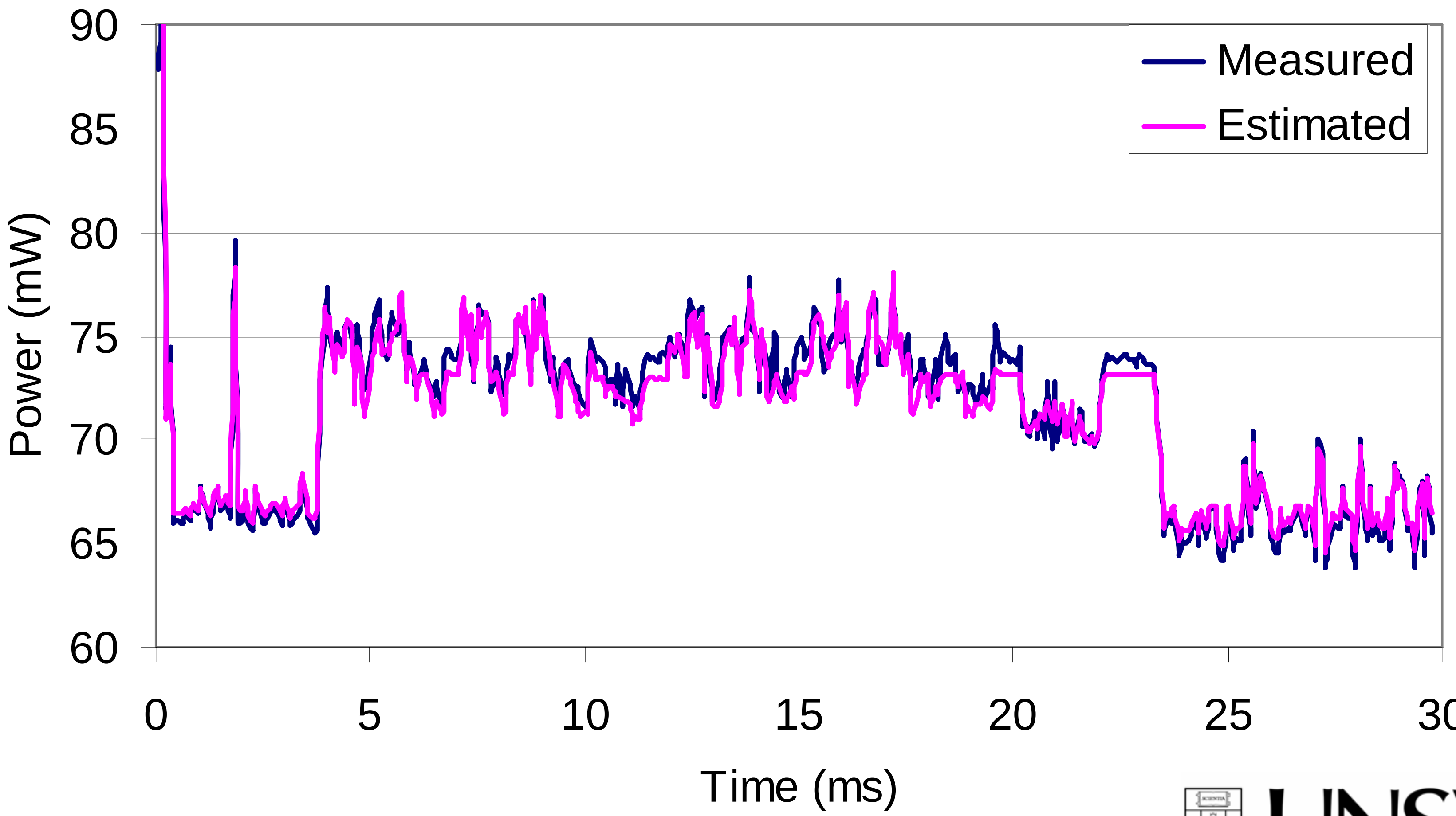
	Original	Modified	% Increase
Gate Area (NANDs)	127,994	134,238	4.9%
Total Power (mW)	77.19	79.48	3.0%

cjpeg



90
85
80
75
70
65
60
Power (mW)
0
5
10
15
20
25
30
Time (ms)
Measured
Estimated

qsort



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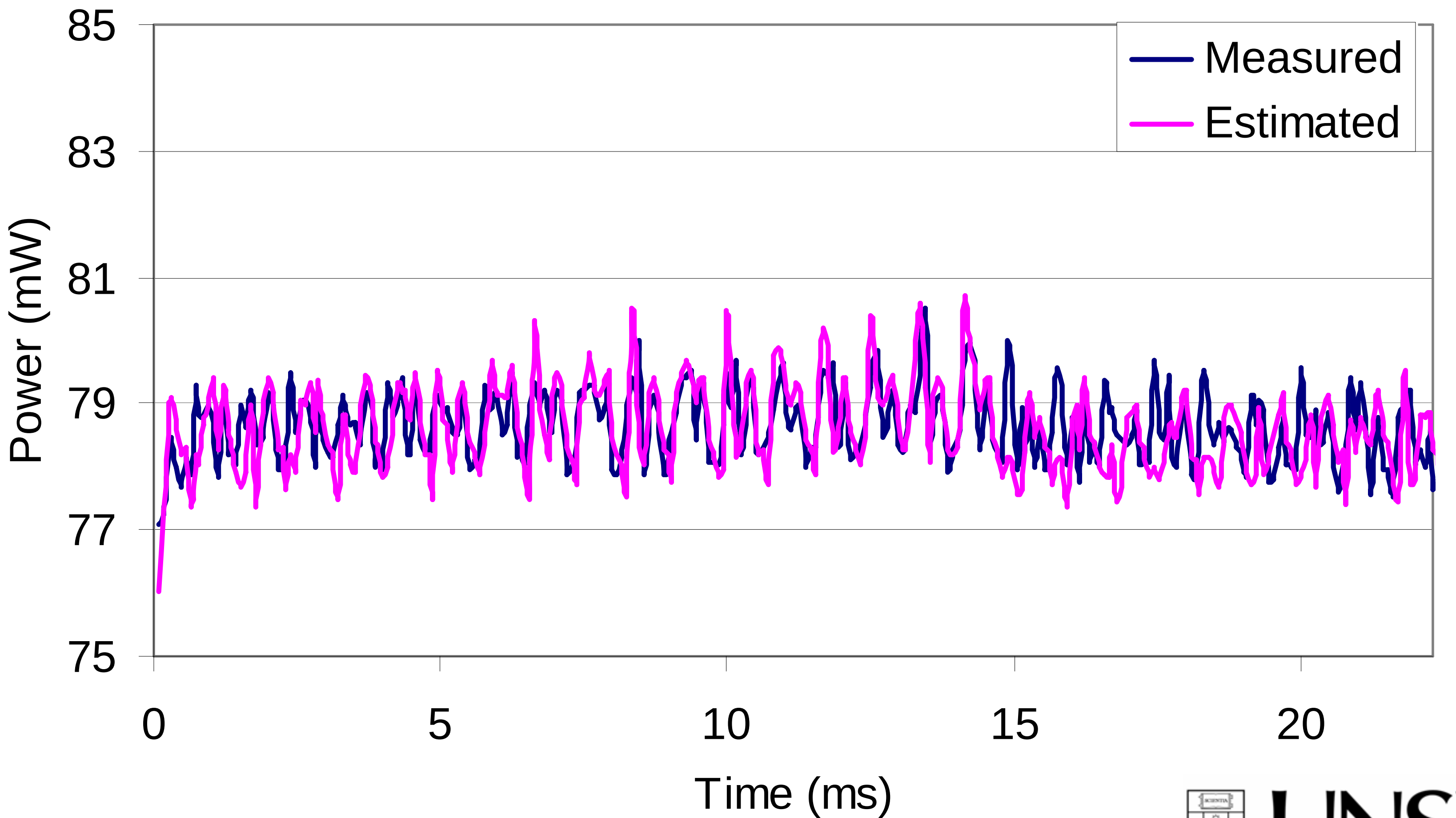
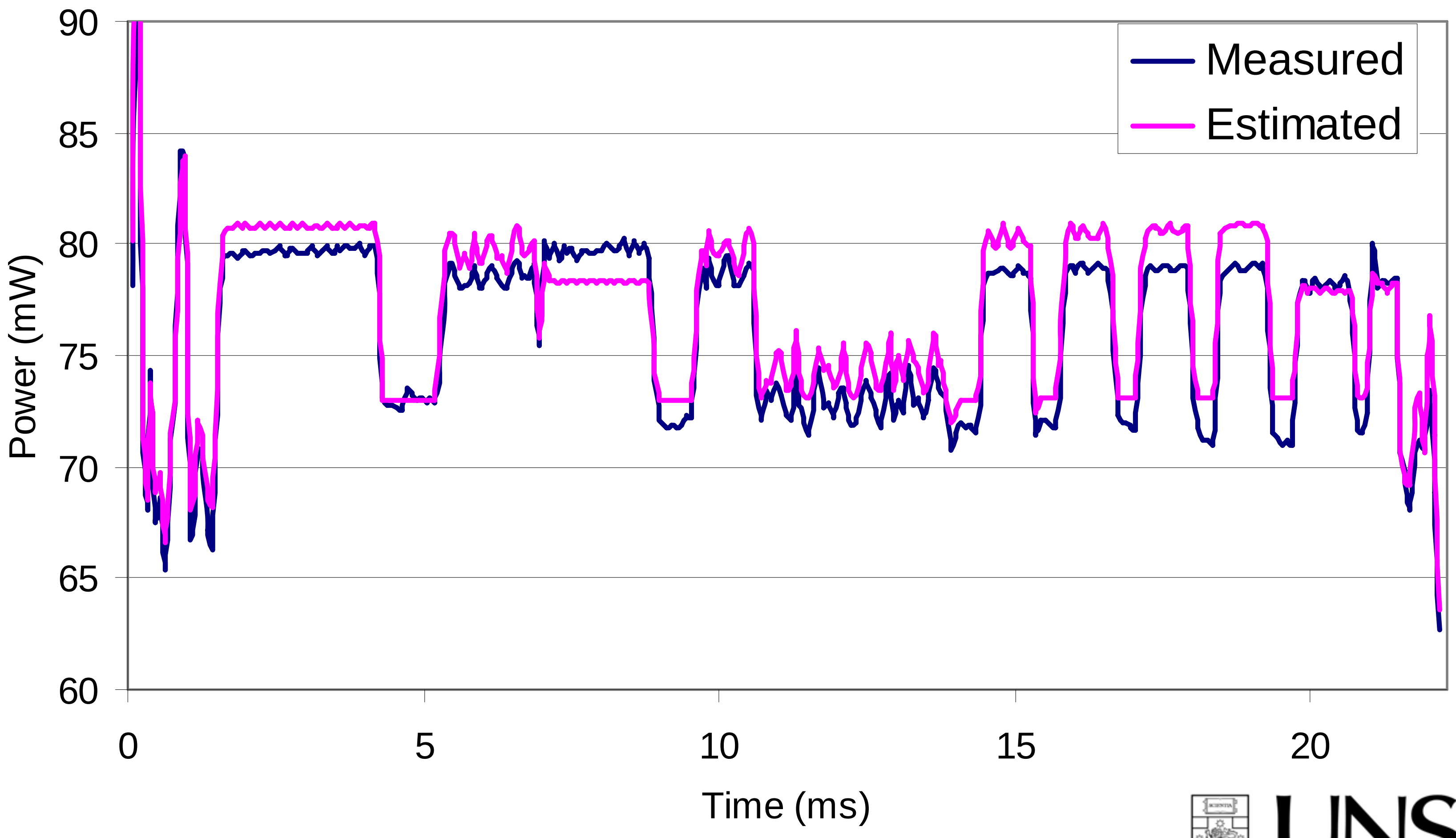
rawcaudio



Measured
Estimated
Power (mW)
85
83
81
79
77
75
0
5
10
15
20
Time (ms)

tiff2rgba



Measured
Estimated
Power (mW)
90
85
80
75
70
65
60
0
5
10
15
20
Time (ms)

Accuracy

Benchmark	Cycles (mils.)	Power Error		Energy (mJ)		Energy Error
		Avg	Max	Measured	Estimated	
g721e	2.9	0.77%	4.97%	1.566	1.577	0.74%
g721d	2.6	0.48%	5.05%	1.441	1.448	0.47%
cjpeg	4.2	1.27%	6.86%	2.559	2.564	0.21%
qsort	3.7	0.85%	4.80%	2.124	2.118	-0.24%
rawcaudio	3.2	1.45%	8.04%	1.988	1.961	-1.35%
rawdaudio	2.9	0.58%	2.30%	1.793	1.793	-0.03%
tiff2bw	3.1	0.89%	6.00%	1.924	1.925	0.03%
tiff2rgba	2.8	1.58%	6.24%	1.685	1.705	1.22%

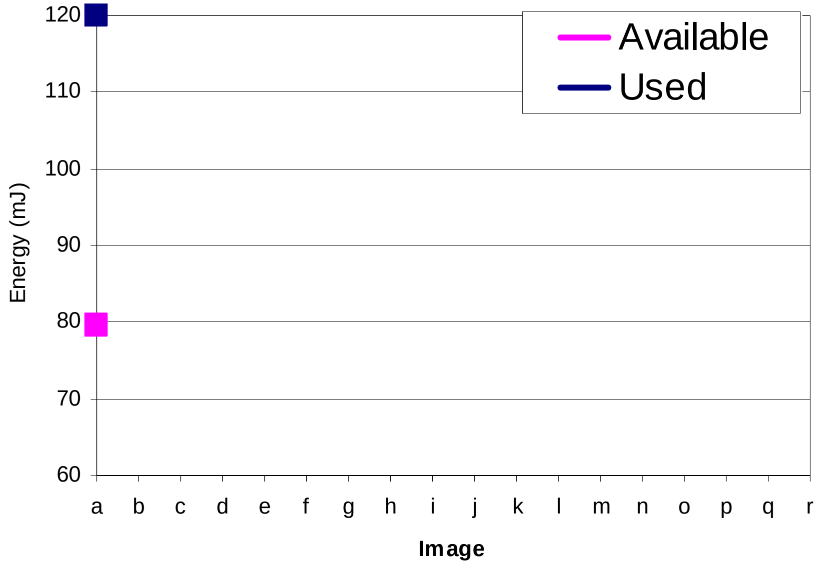
Example Application

Available Energy per image:

79.7 mJ

Energy used for this image:

120.3 mJ

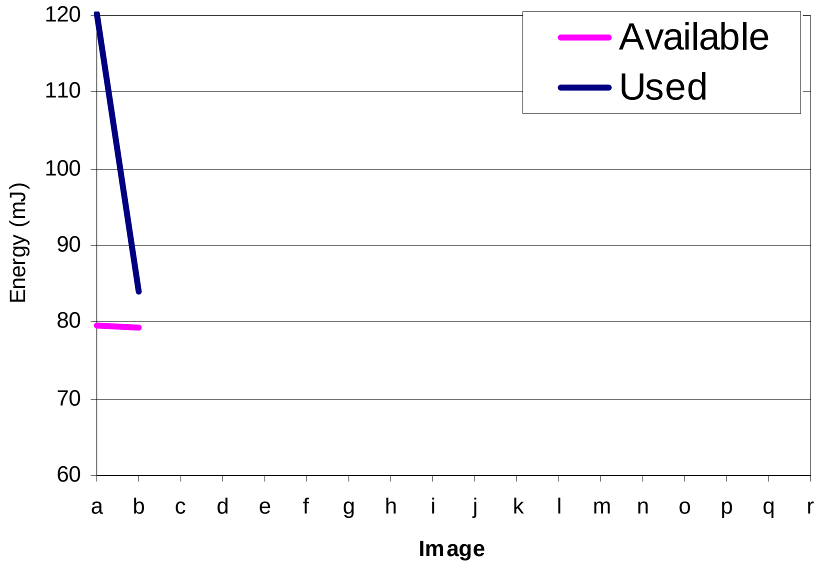


Level 12 → Level 4

Example Application

Available Energy per image: 79.4 mJ

Energy used for this image: 83.9 mJ



Level 4 → Level 2

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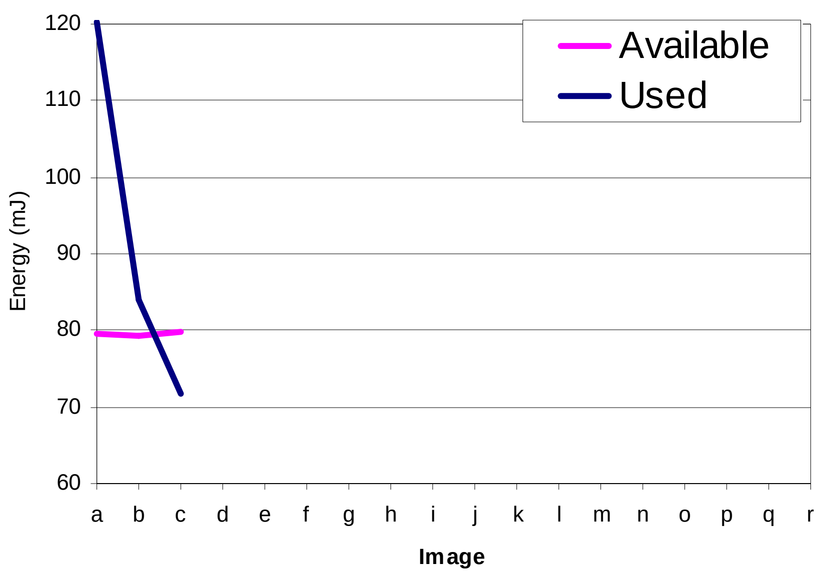
Example Application

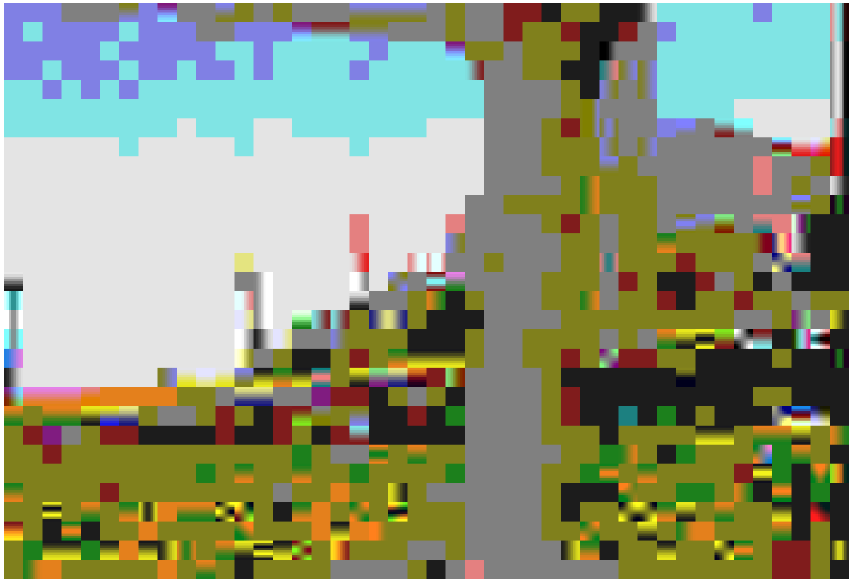
Available Energy per image:

79.9 mJ

Energy used for this image:

71.7 mJ





Level 2 → Level 3

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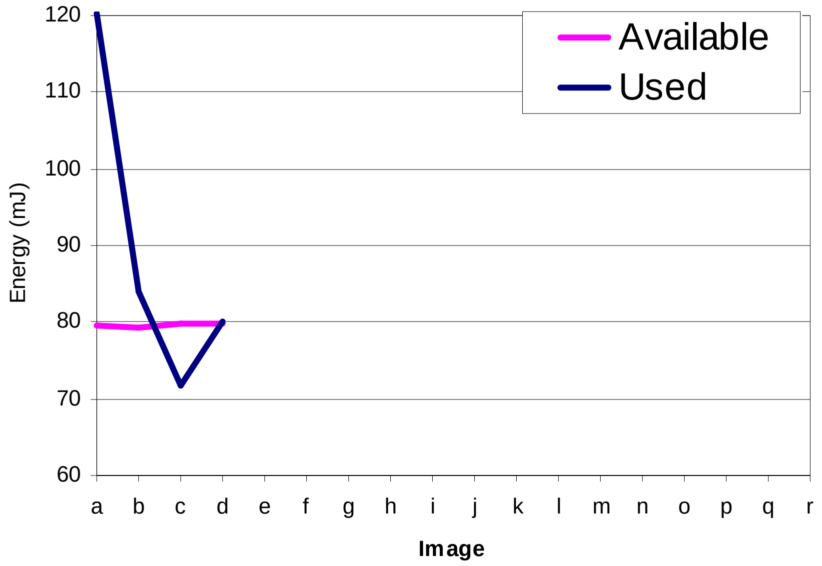
Example Application

Available Energy per image:

79.9 mJ

Energy used for this image:

80.2 mJ



Level 3 → Level 2

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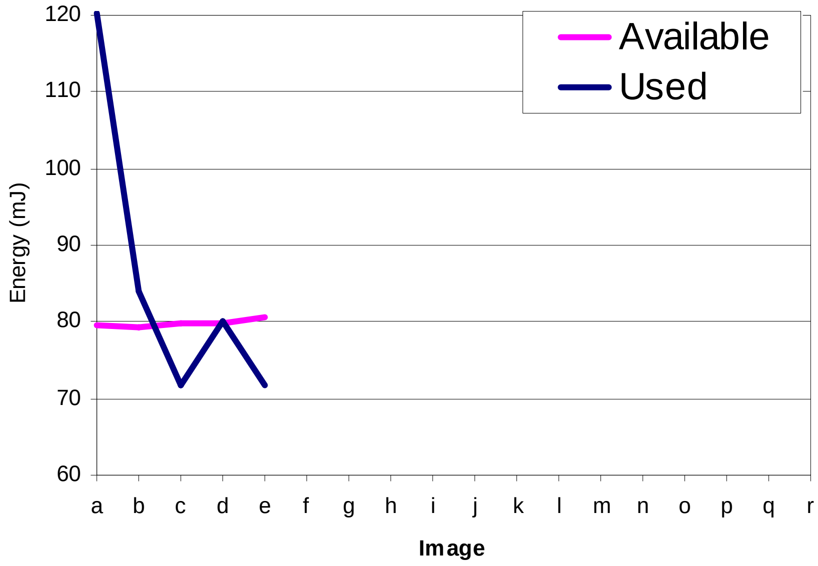
Example Application

Available Energy per image:

80.5 mJ

Energy used for this image:

71.8 mJ



Level 2 → Level 3

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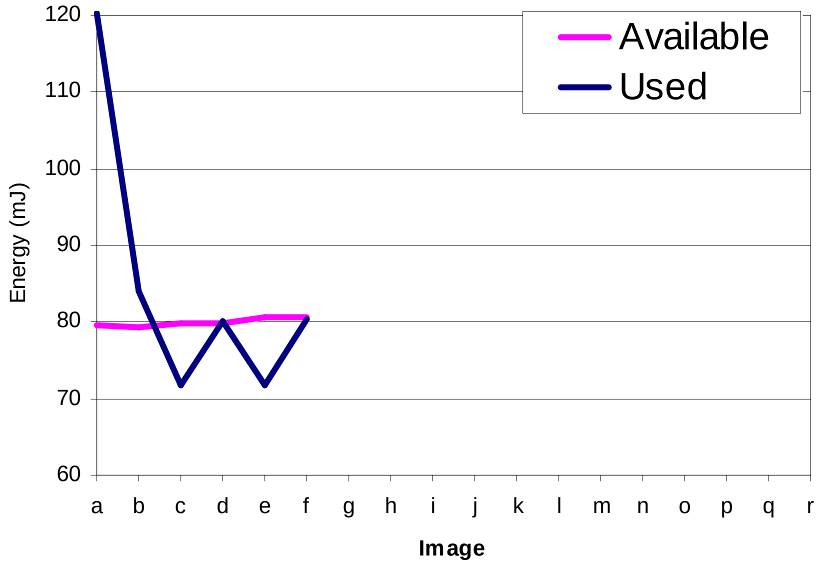
Example Application

Available Energy per image:

80.5 mJ

Energy used for this image:

80.2 mJ



Level 3 → Level 3

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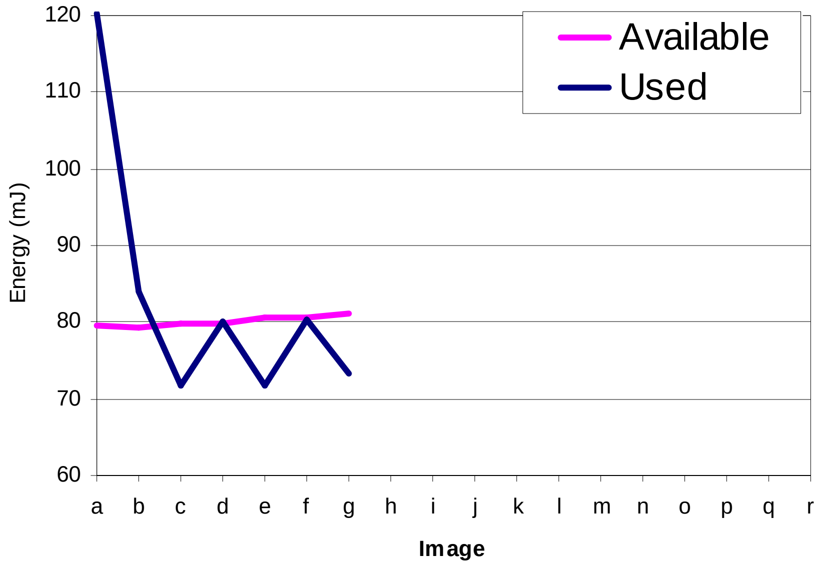
Example Application

Available Energy per image:

81.2 mJ

Energy used for this image:

73.3 mJ



Level 3 → Level 4

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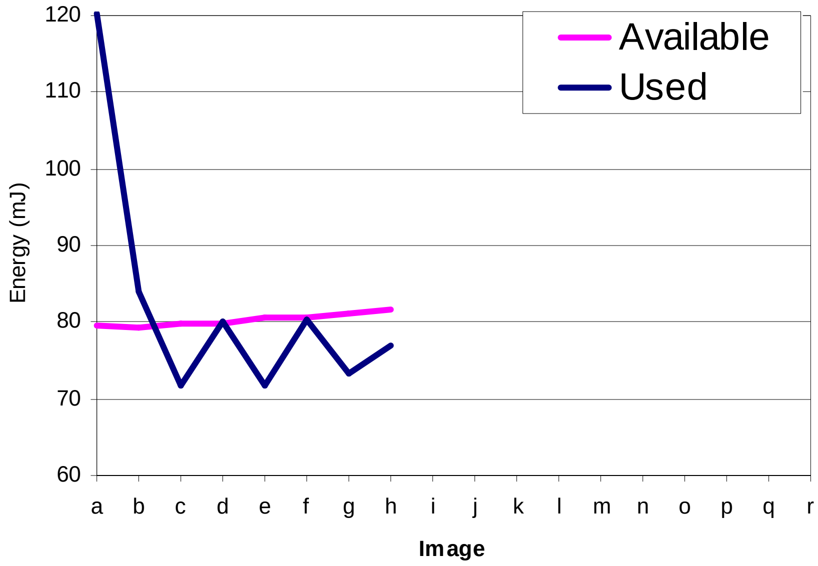
Example Application

Available Energy per image:

81.6 mJ

Energy used for this image:

77.0 mJ



Level 4 → Level 4

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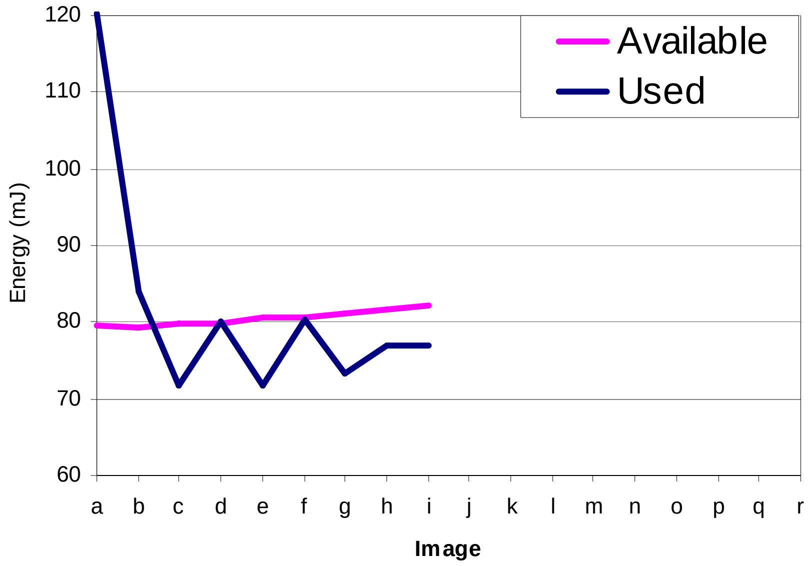
Example Application

Available Energy per image:

82.1 mJ

Energy used for this image:

76.8 mJ



Level 4 → Level 4

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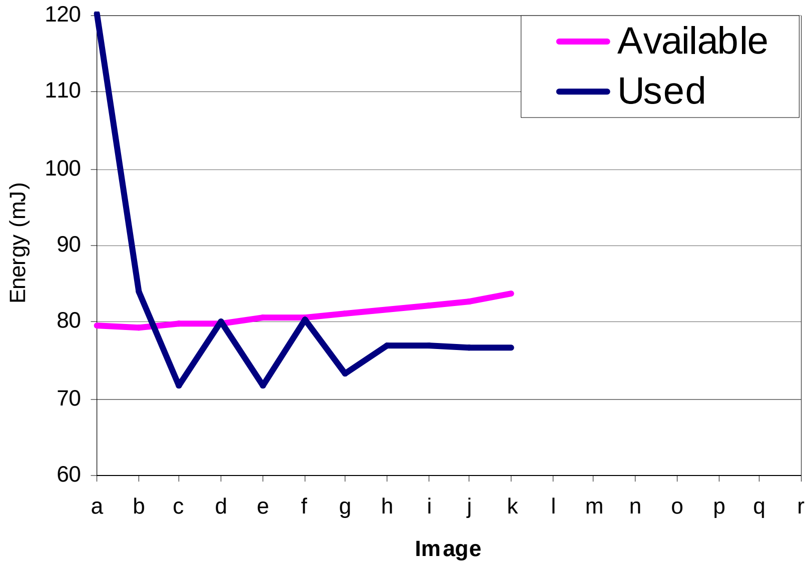
Example Application

Available Energy per image: 82.8 mJ

Energy used for this image: 76.8 mJ



Level 4 → Level 4

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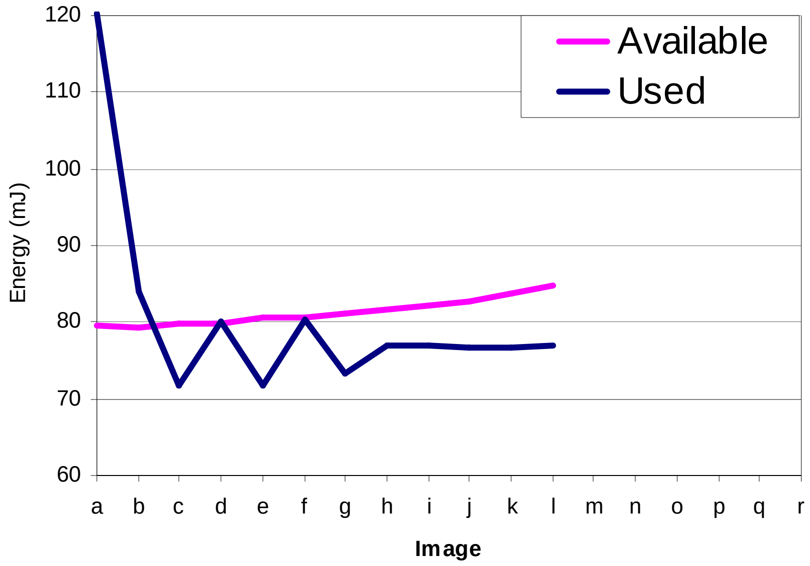
Example Application

Available Energy per image:

83.7 mJ

Energy used for this image:

76.8 mJ



Level 4 → Level 4

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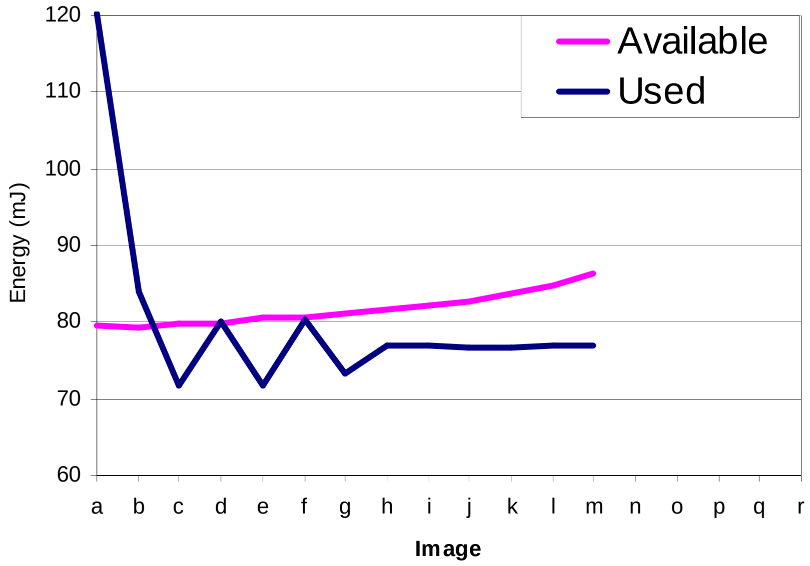
Example Application

Available Energy per image:

84.8 mJ

Energy used for this image:

76.9 mJ



Level 4 → Level 5

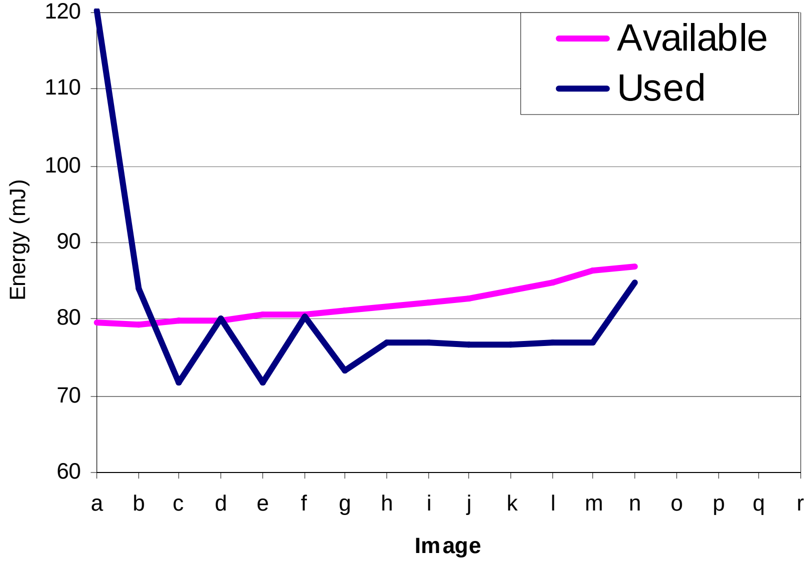
Example Application

Available Energy per image:

86.8 mJ

Energy used for this image:

84.7 mJ



Level 5 → Level 5

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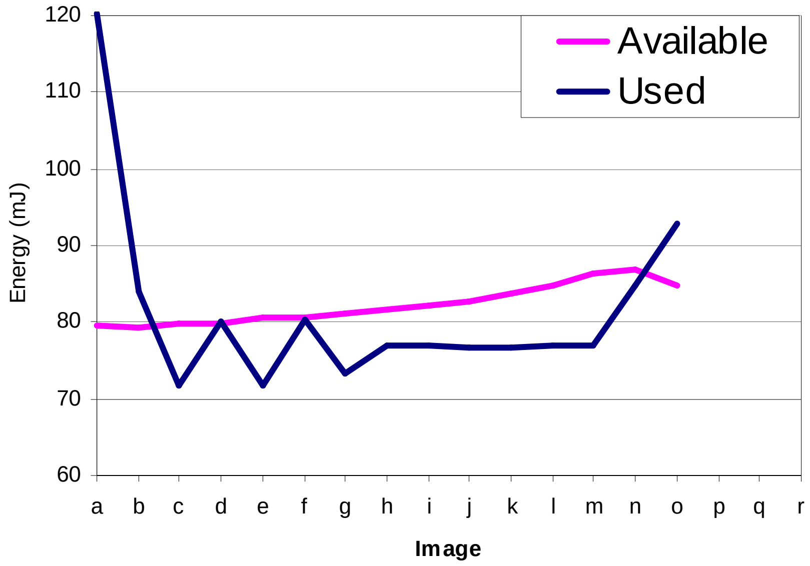
Example Application

Available Energy per image:

84.8 mJ

Energy used for this image:

92.8 mJ



Level 5 → Level 4

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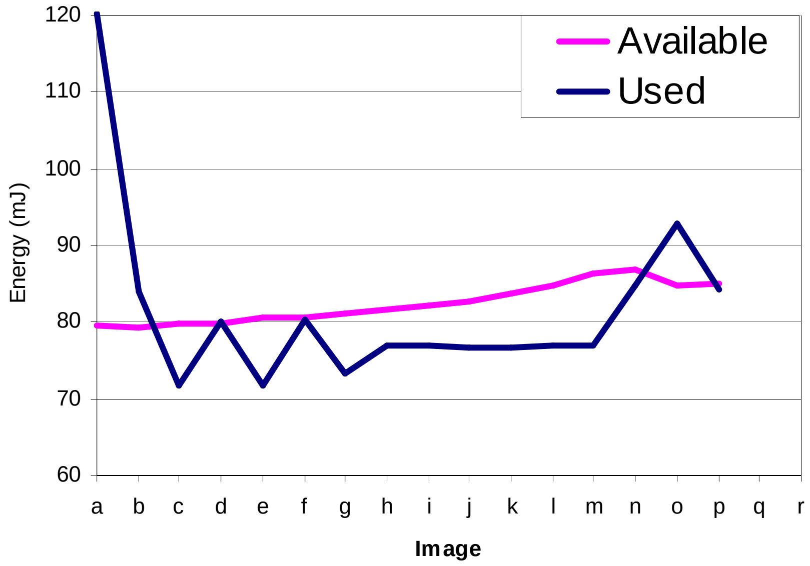
Example Application

Available Energy per image:

84.9 mJ

Energy used for this image:

84.4 mJ



Level 4 → Level 4

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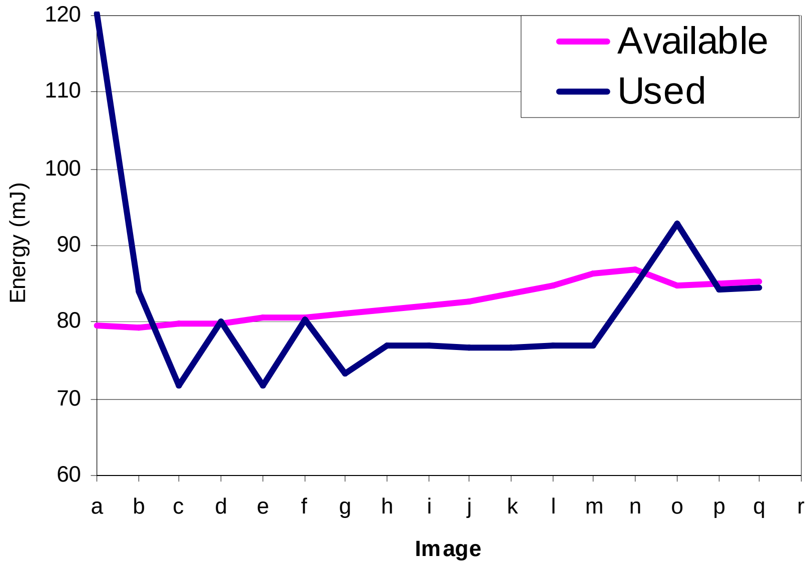
Example Application

Available Energy per image:

85.4 mJ

Energy used for this image:

84.5 mJ



Level 4 → Level 4

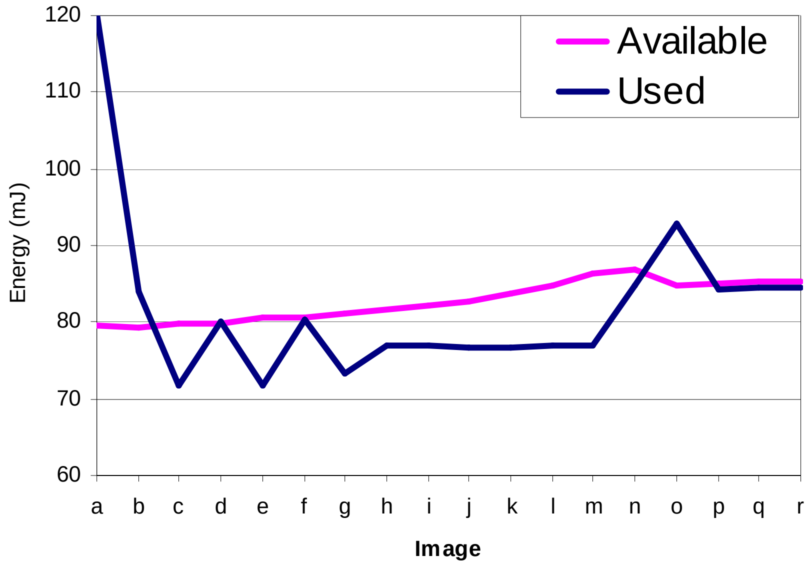
Example Application

Available Energy per image:

1 mJ

Energy used for this image:

84.5 mJ



Level 4 → Level 4

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Summary

- Power feedback is highly desired
- Estimation provides feasible approach to provide this data
- CLIPPER methodology provides high accuracy with low impact
- Examples demonstrate usefulness of power feedback for dynamic approaches

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Questions?

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