Approximate Storage in Solid-State Memories

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MICRO 2013

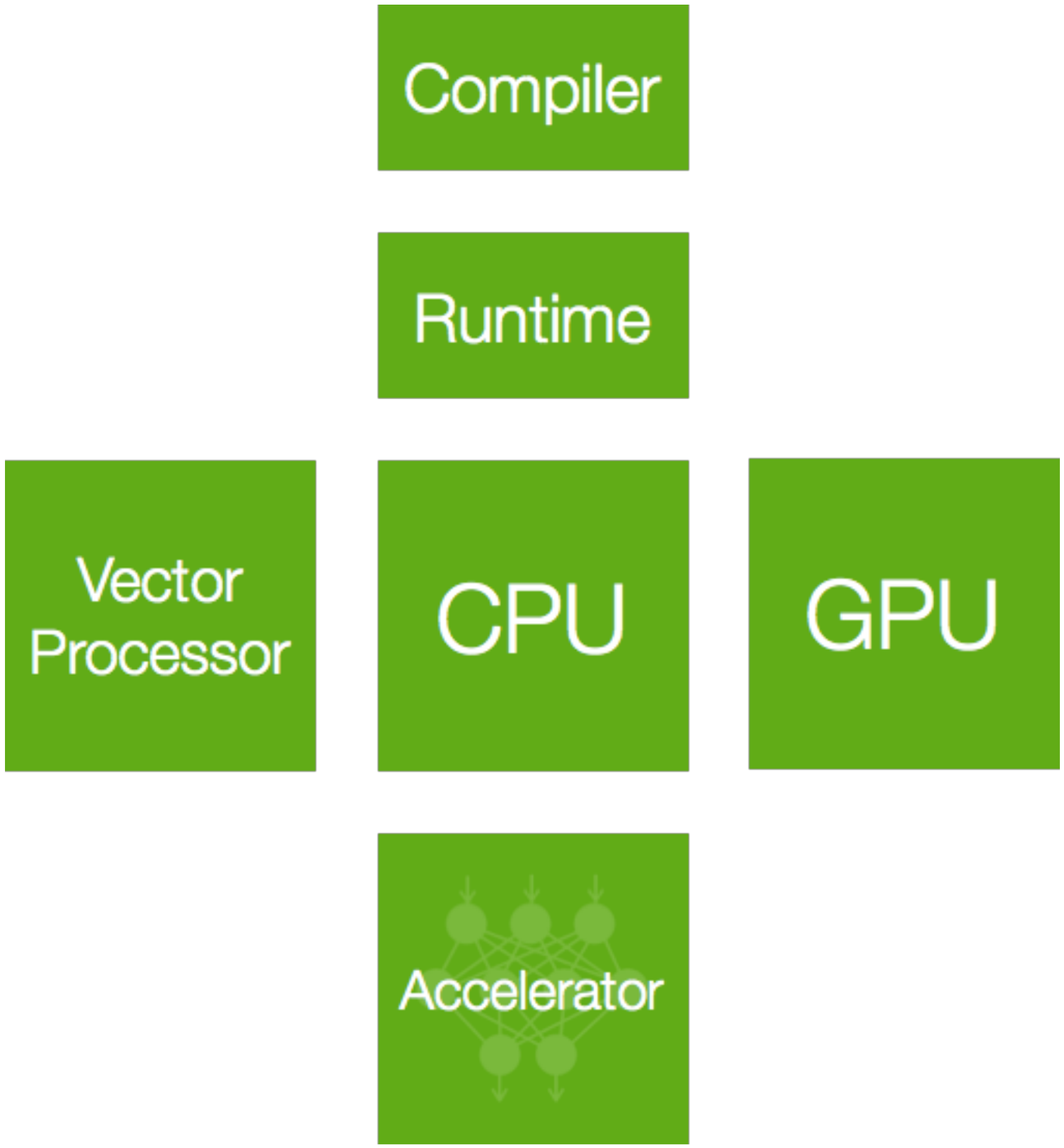
Microsoft Research

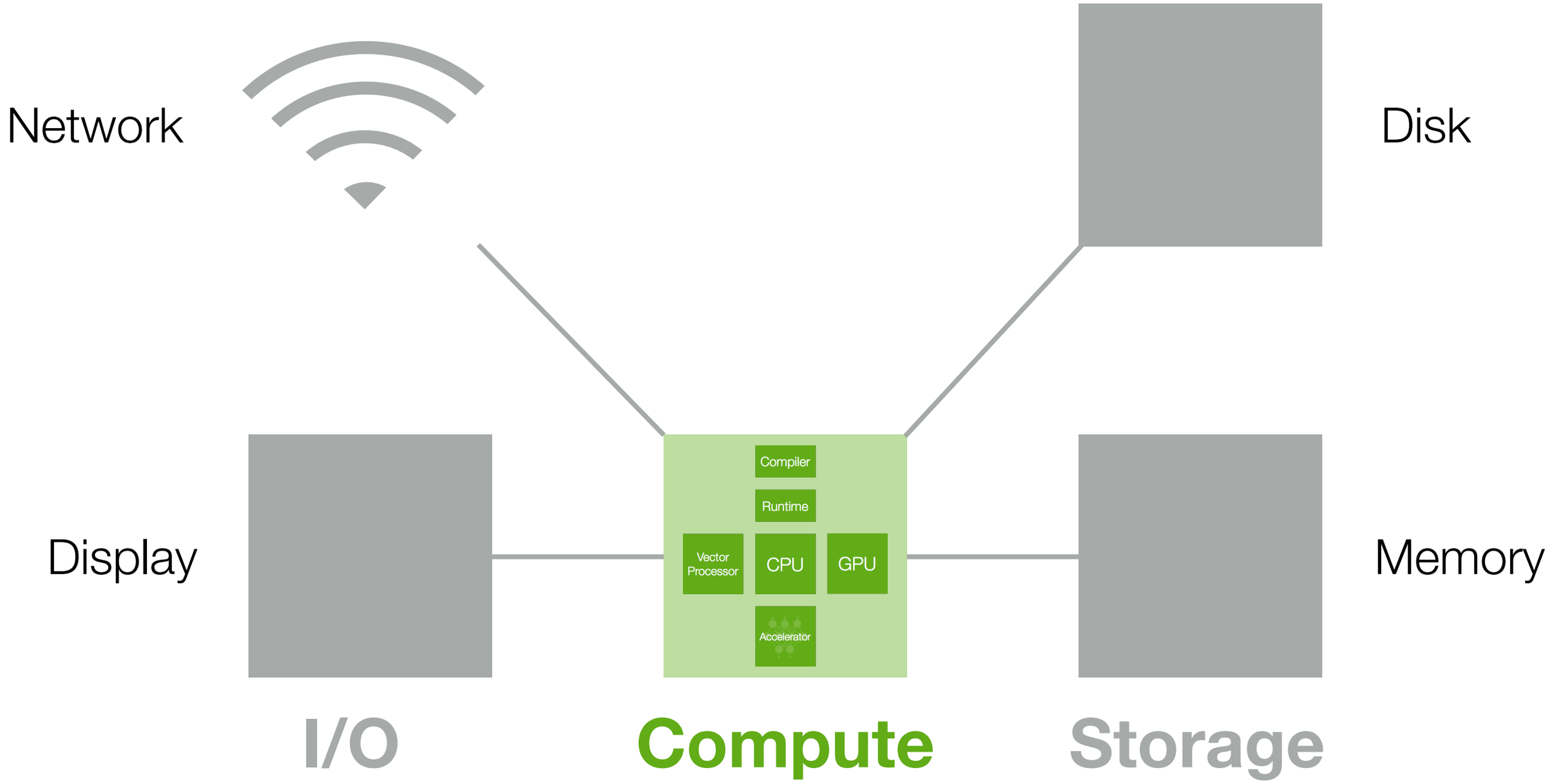
sampa

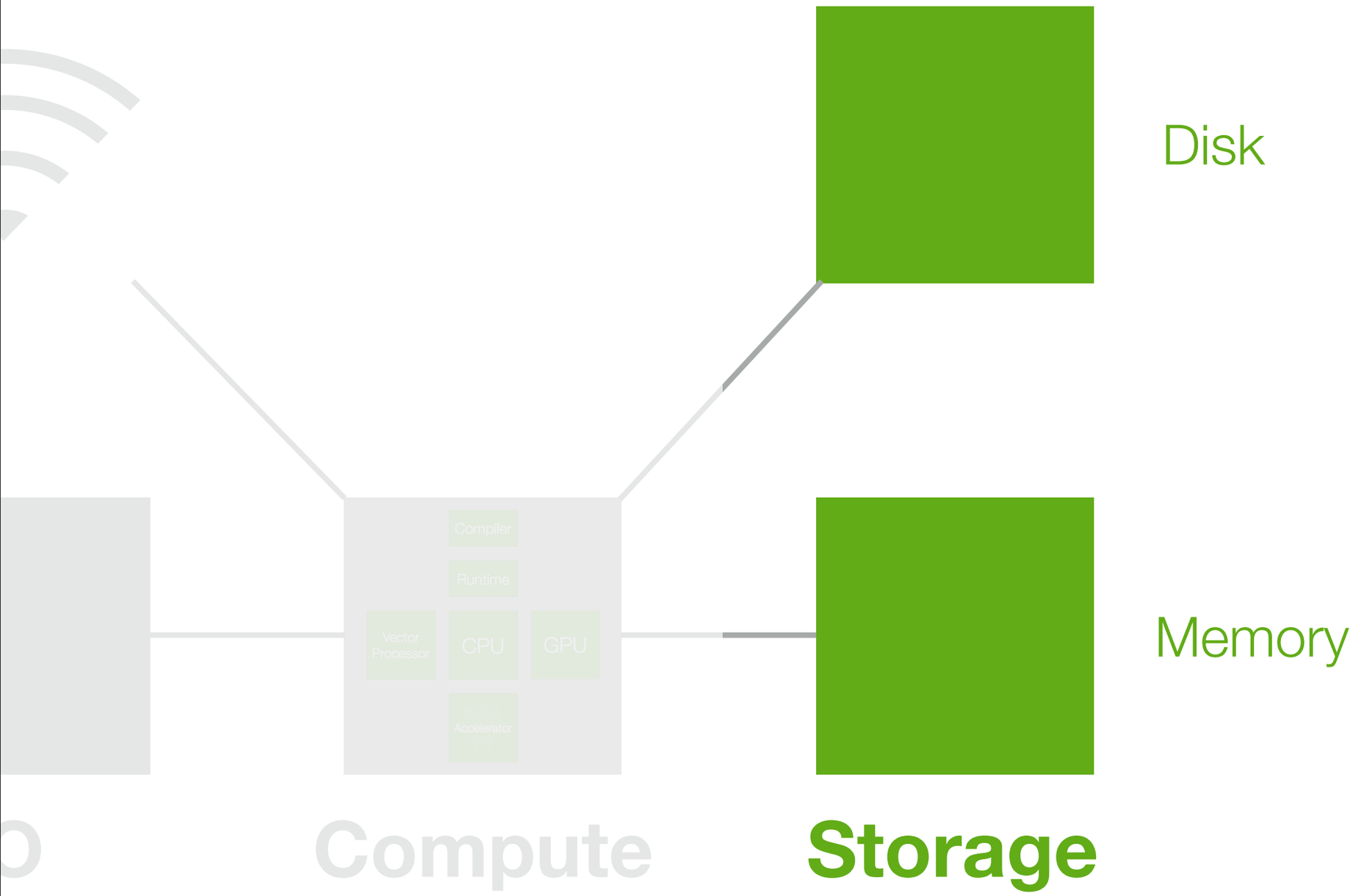
Compiler

Runtime

CPU


Compiler
Runtime
Vector Processor
CPU
GPU
Accelerator


Network
Disk
Display
Memory
Compiler
Runtime
Vector Processor
CPU
GPU
Accelerator
I/O
Compute
Storage


Disk
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Storage


vodafone UK 5:32 PM
General
Usage
22.5 GB Available
34.6 GB Used
Music
15.9 GB
Photos & Camera
11.3 GB
TripAdvisor
City Guides
549 MB
Stay.com
stay
535 MB
Keynote
389 MB
Podcasts
375 MB
Evernote


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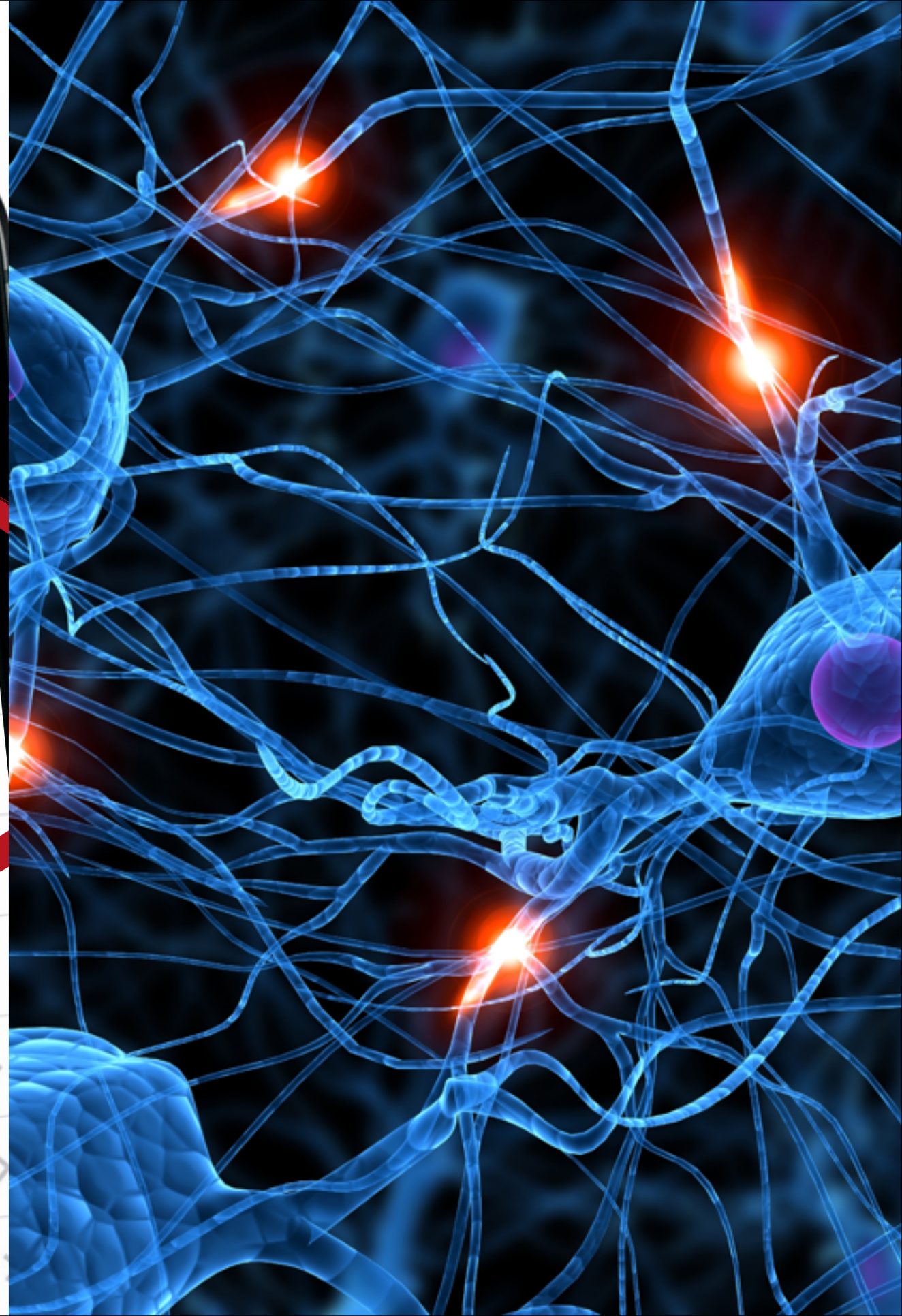


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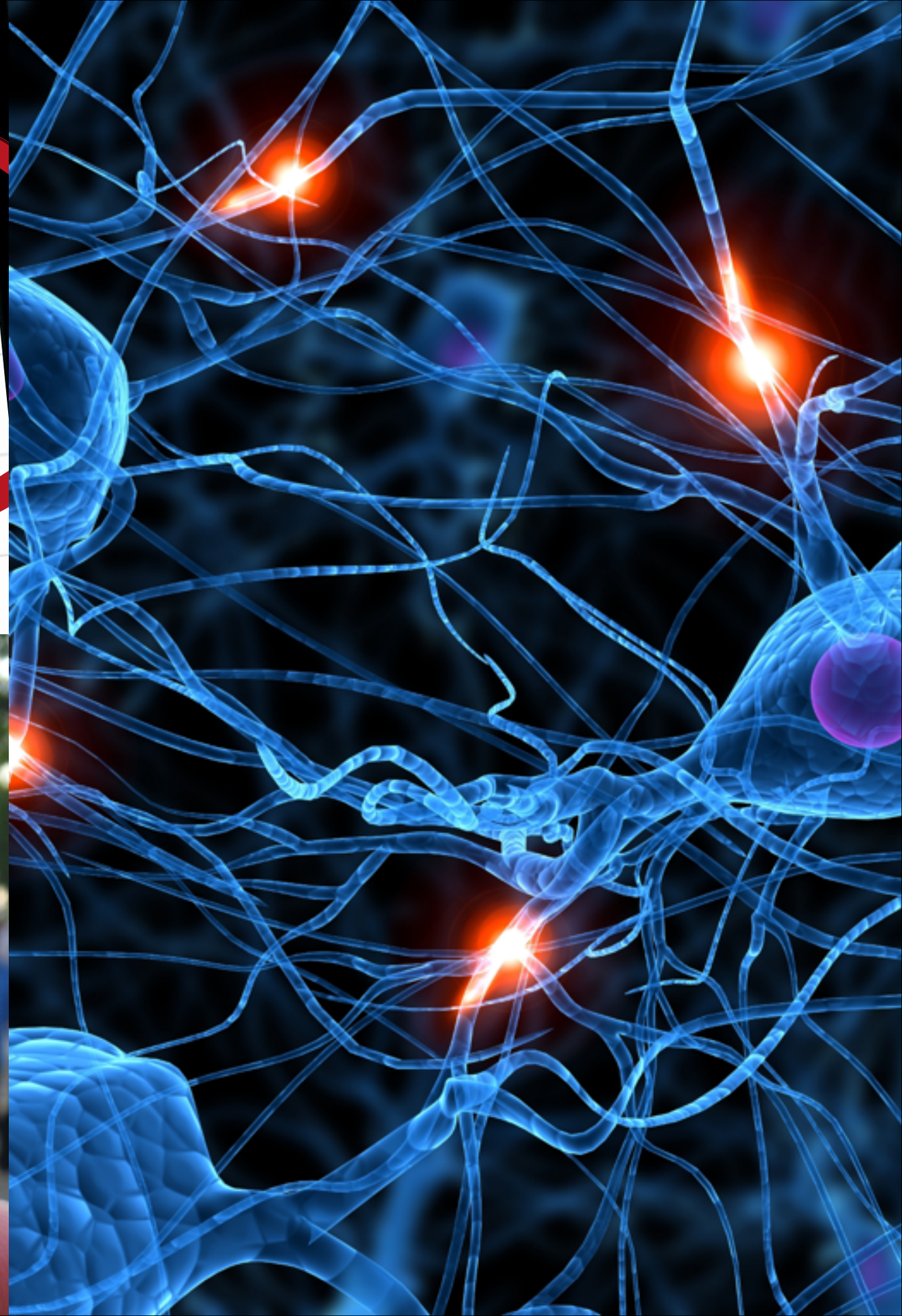
Beverley Street
Beverley S
Dundas Street W

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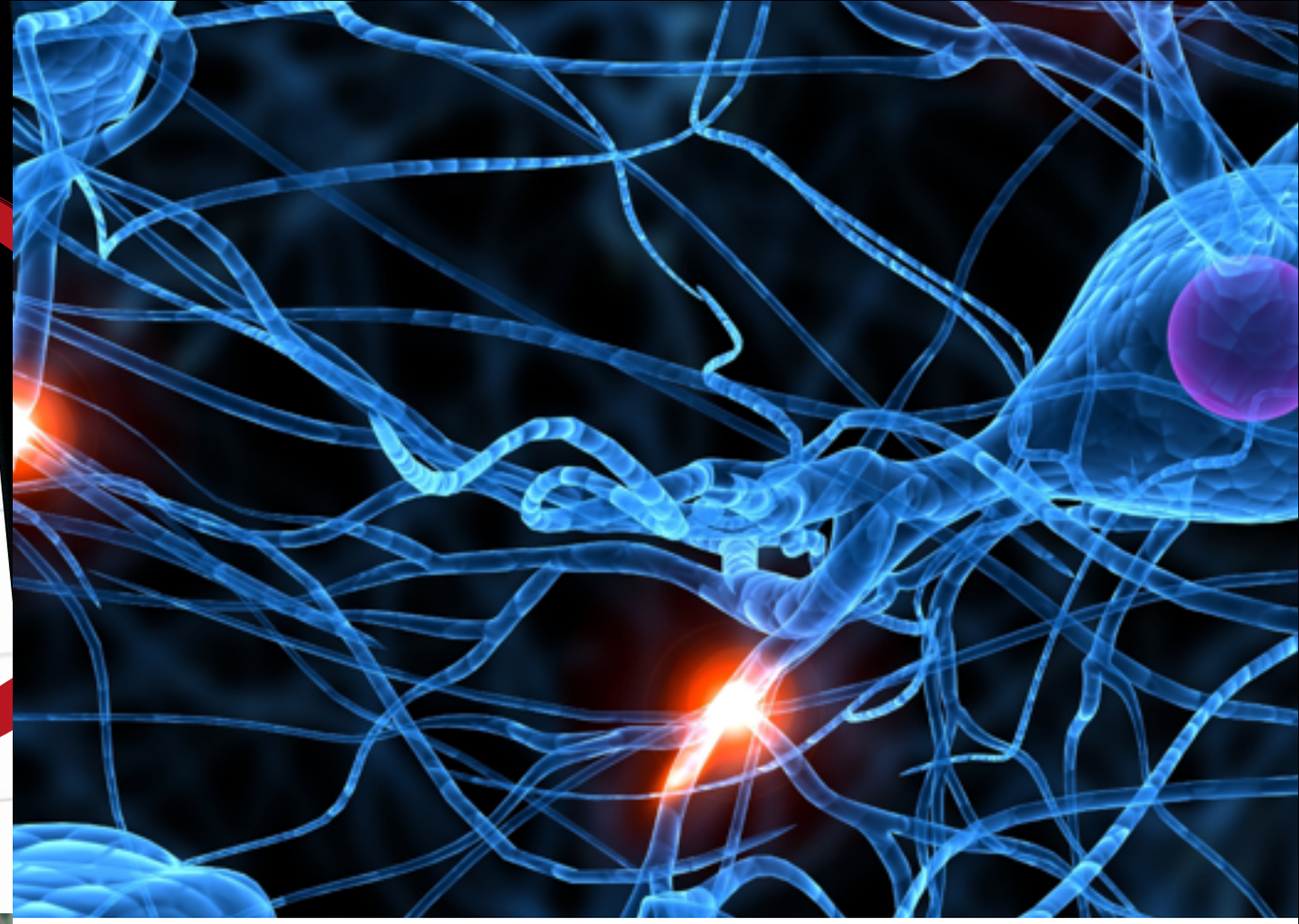
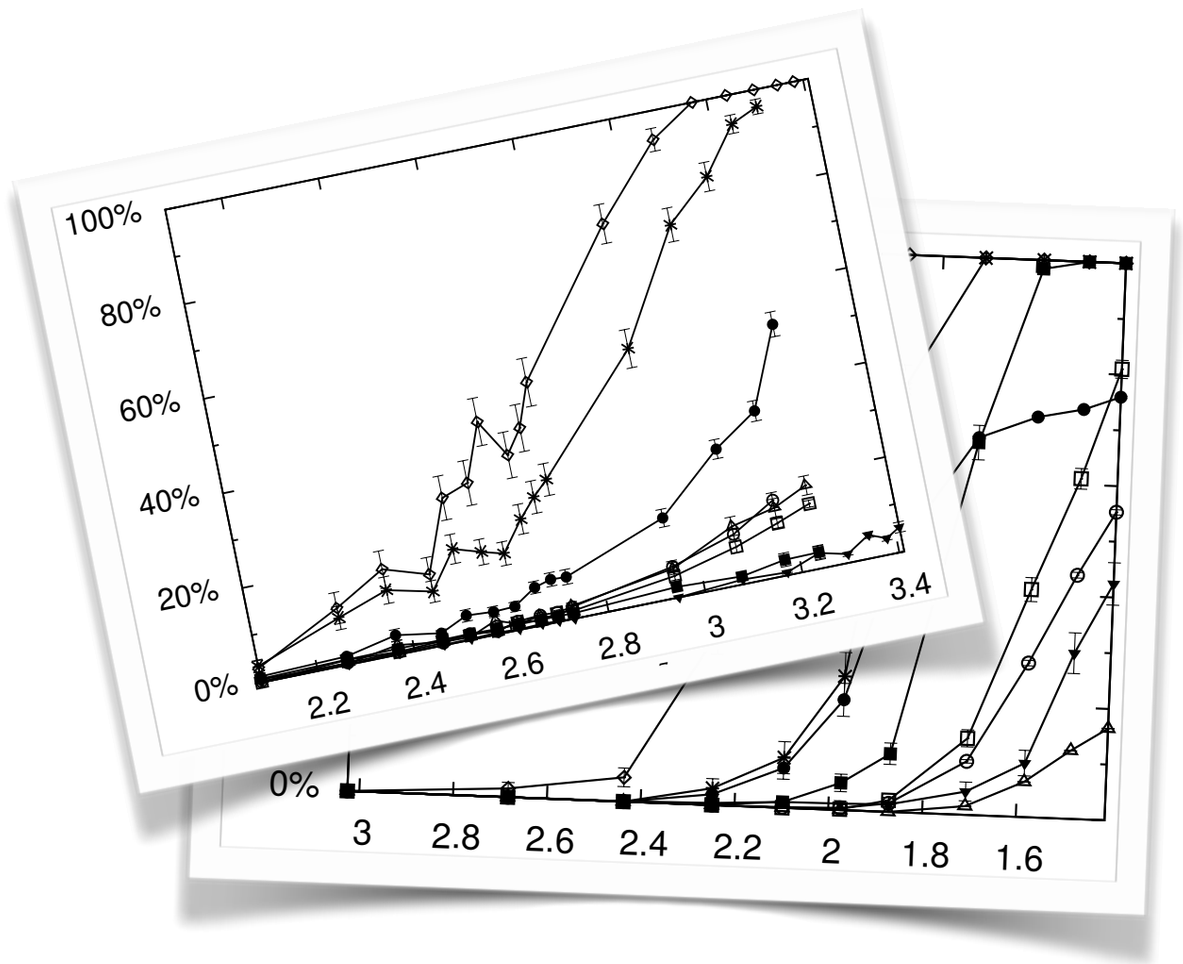
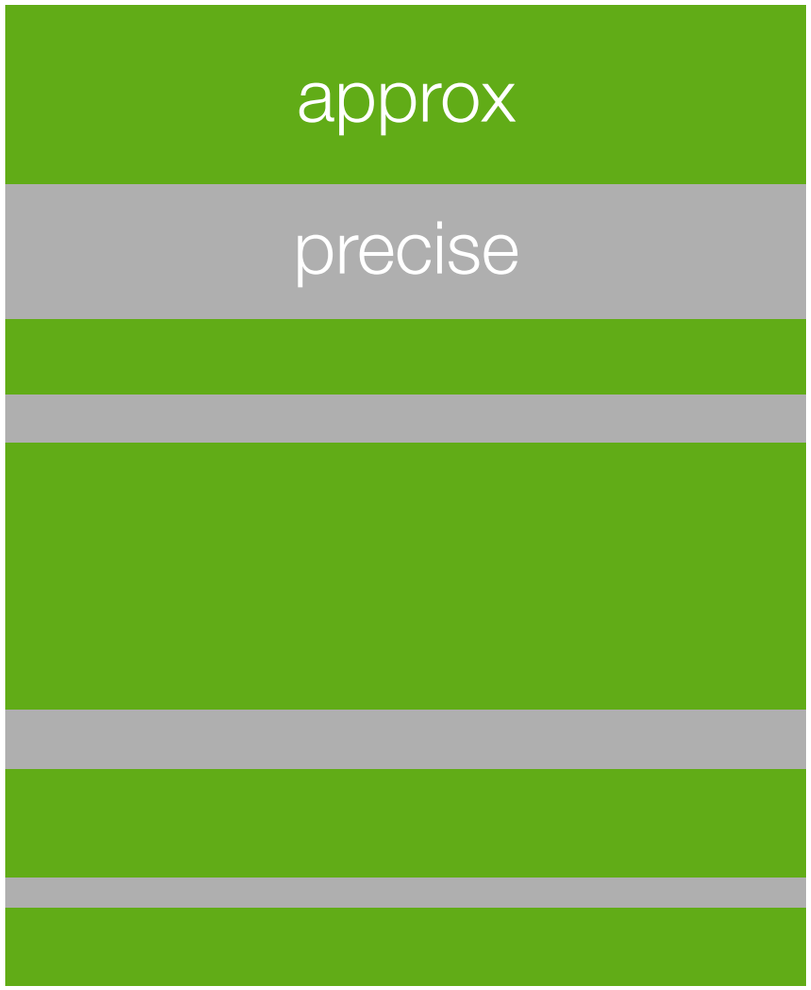


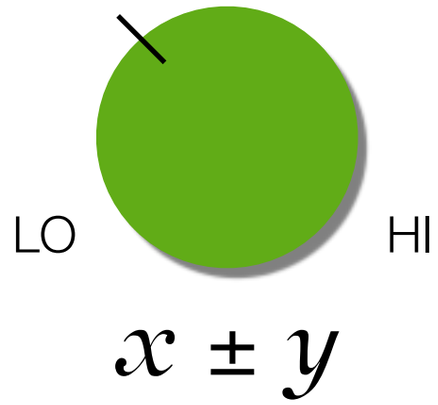

Beverley S
Dundas


100%
80%
60%
40%
20%
0%
2.2
2.4
2.6
2.8
3
3.2
3.4
0%
3
2.8
2.6
2.4
2.2
2
1.8
1.6

Themes
in approximate computing

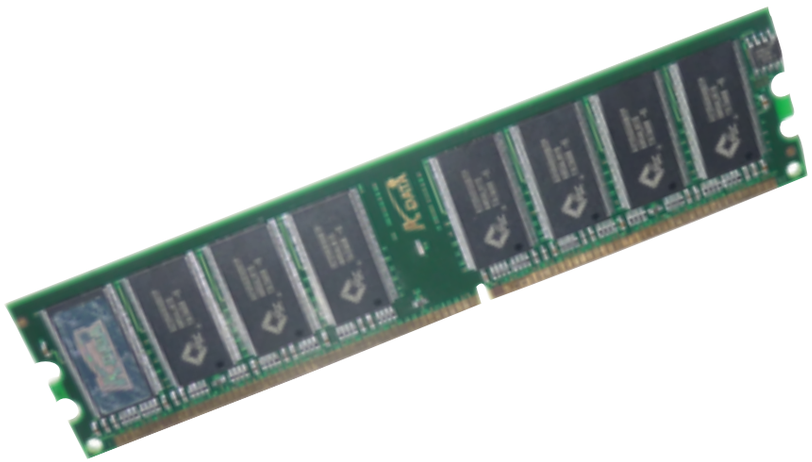


Interleaving:
Programs are both approximate & precise



Error mitigation:
Exploit the hardware to minimize error

Phase-change memory (PCM) :)



+

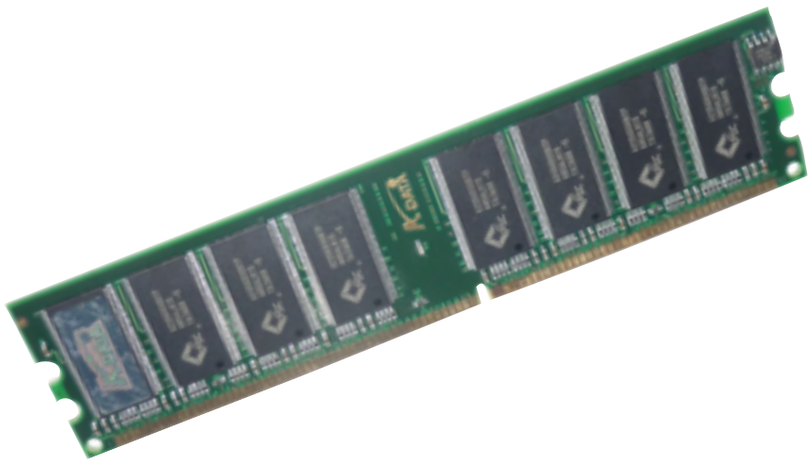
Surpass DRAM's scaling limits

"Almost" as fast as DRAM

Non-volatile

Faster than flash

Phase-change memory (PCM) :(



+

Write speed
& energy

Cells wear out
over time

Phase-change memory (PCM) :(

Multi-level cells are denser
but need more time and energy.

Cells **wear out** over time
and can no longer be used.

Phase-change memory (PCM) :(

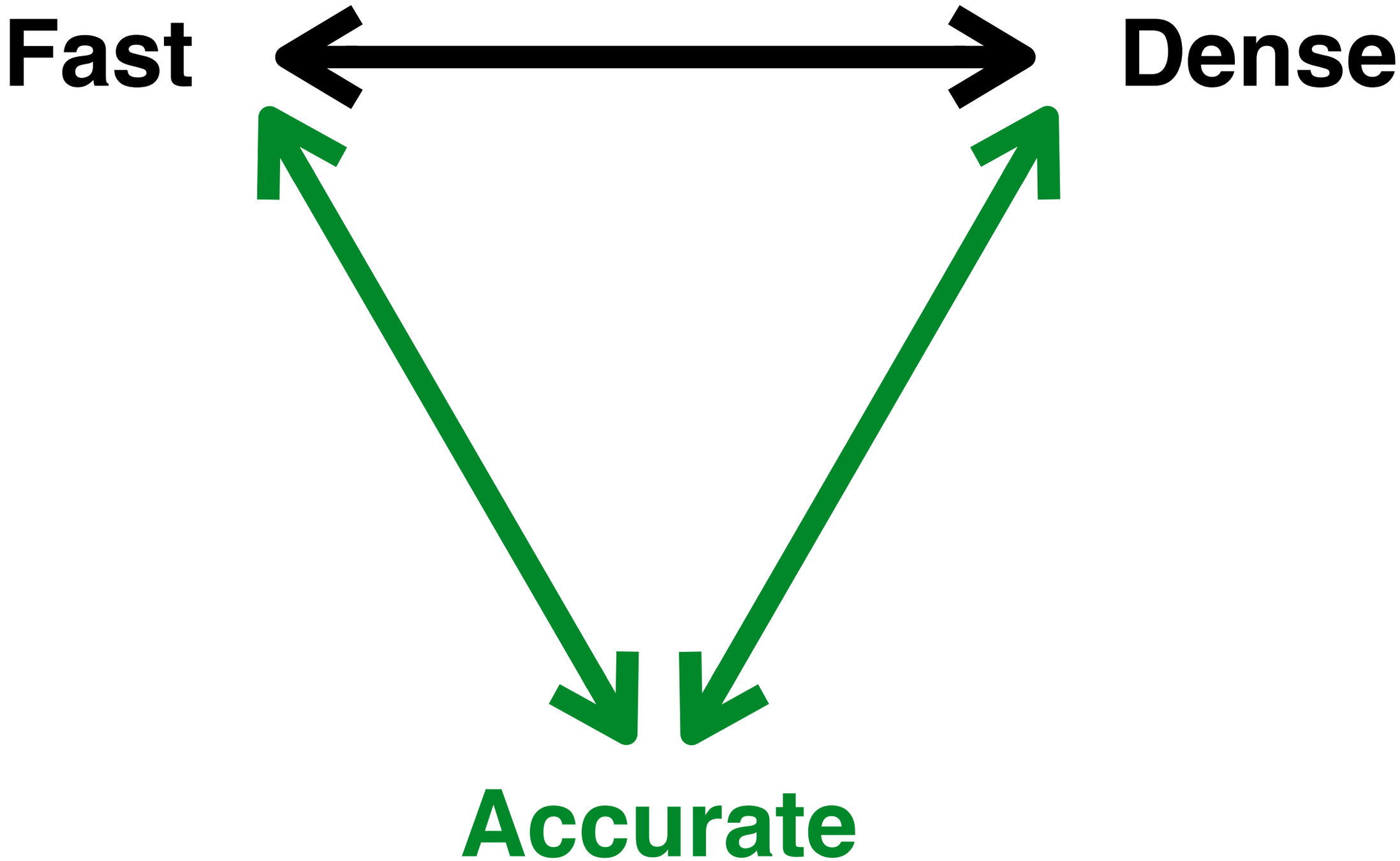
Multi-level cells are denser
but need more time and energy
to protect against errors.

Cells **wear out** over time
and can no longer be used
for precise data storage.

Phase-change memory (PCM) :)

Fast  **Dense**

Phase-change memory (PCM) :)



Approximate storage in PCM

Trade off accuracy for performance in **multi-level cell** accesses.

Use **worn-out** memory for approximate data instead of throwing it away.

Approximate storage in PCM

1. Trade off accuracy for performance in **multi-level cell** accesses.

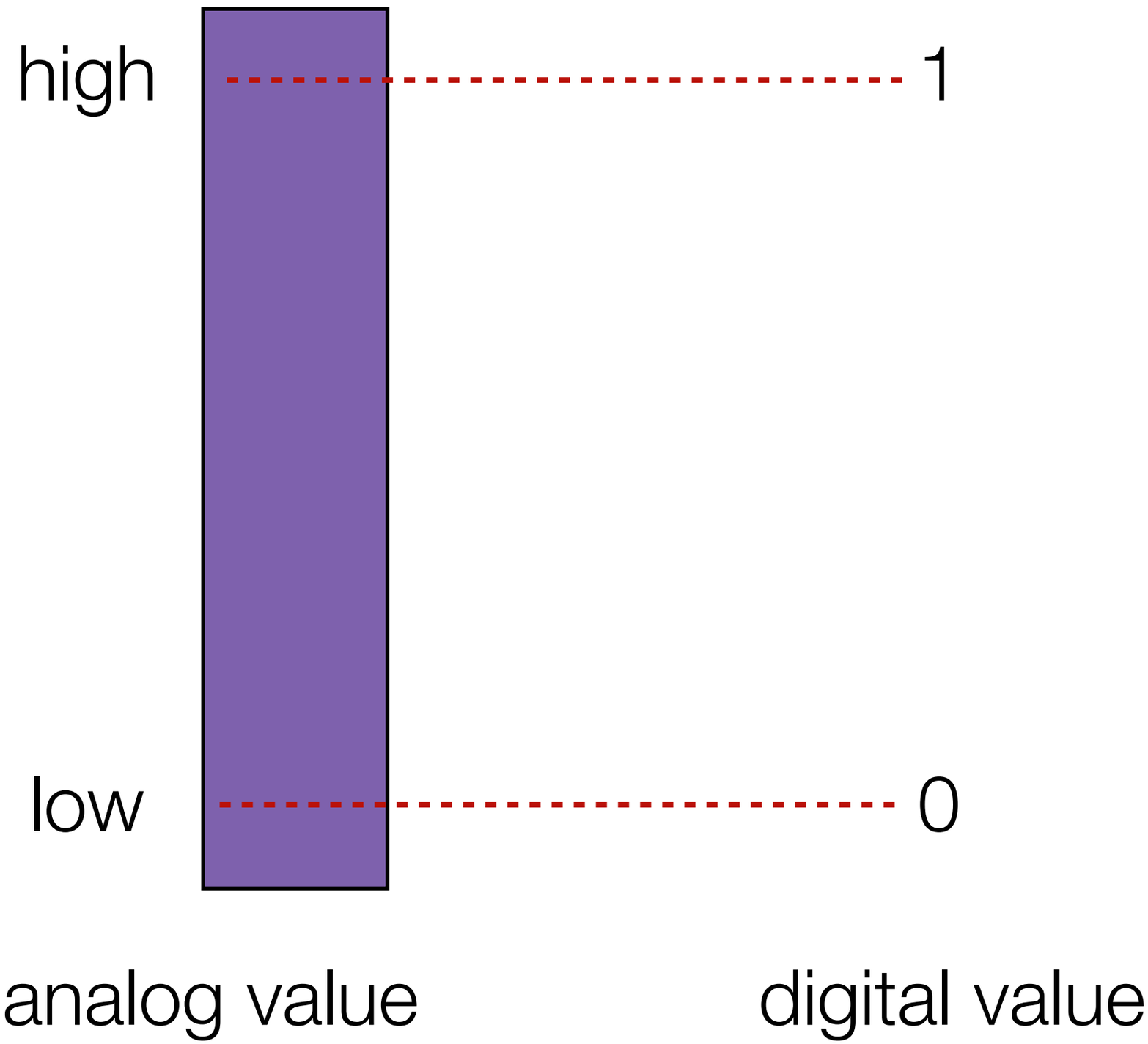
2. Use **worn-out** memory for approximate data instead of throwing it away.

Approximate storage in PCM

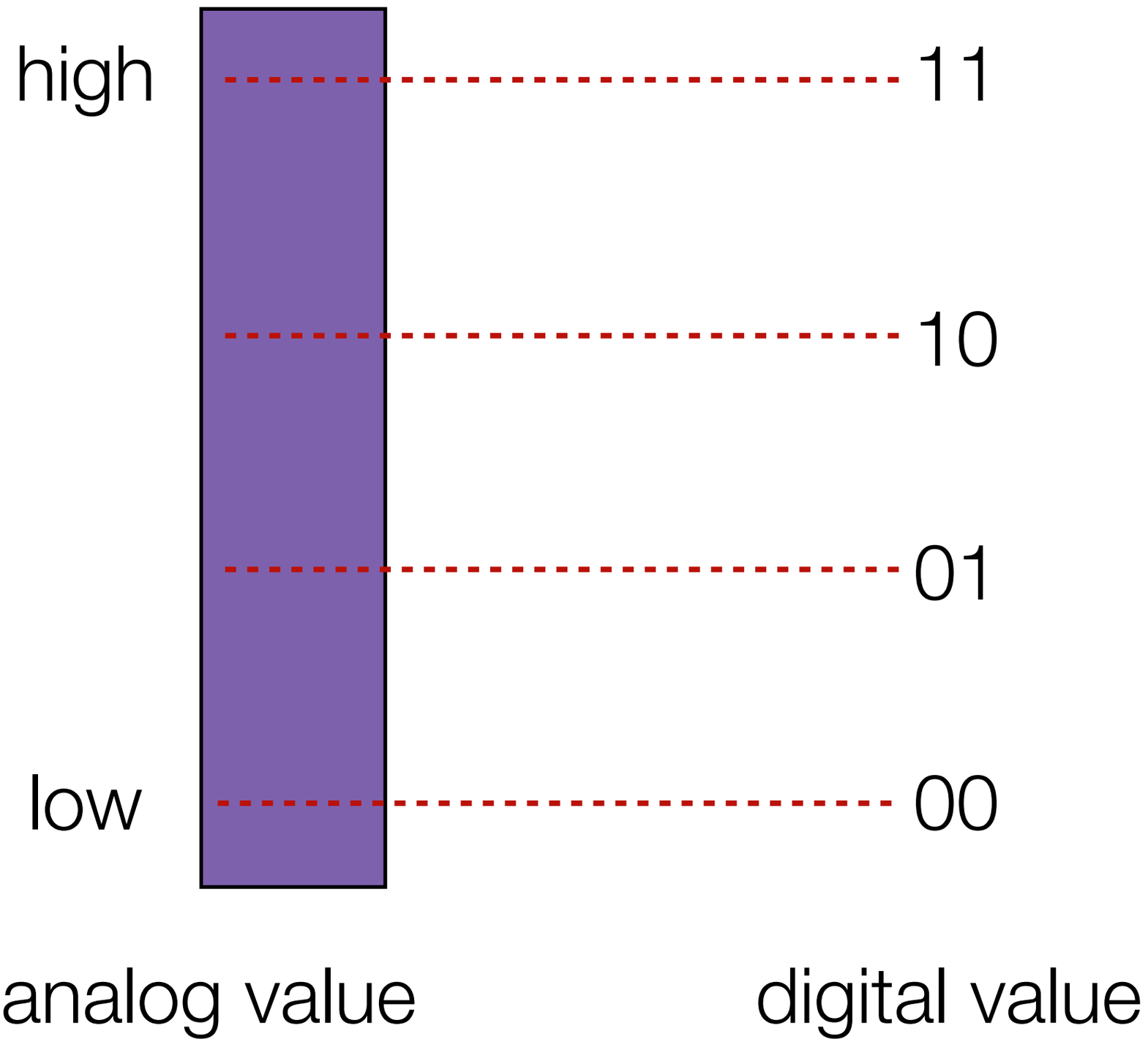
1 Trade off accuracy for performance in **multi-level cell** accesses.

2 Use approximate throwing it away.

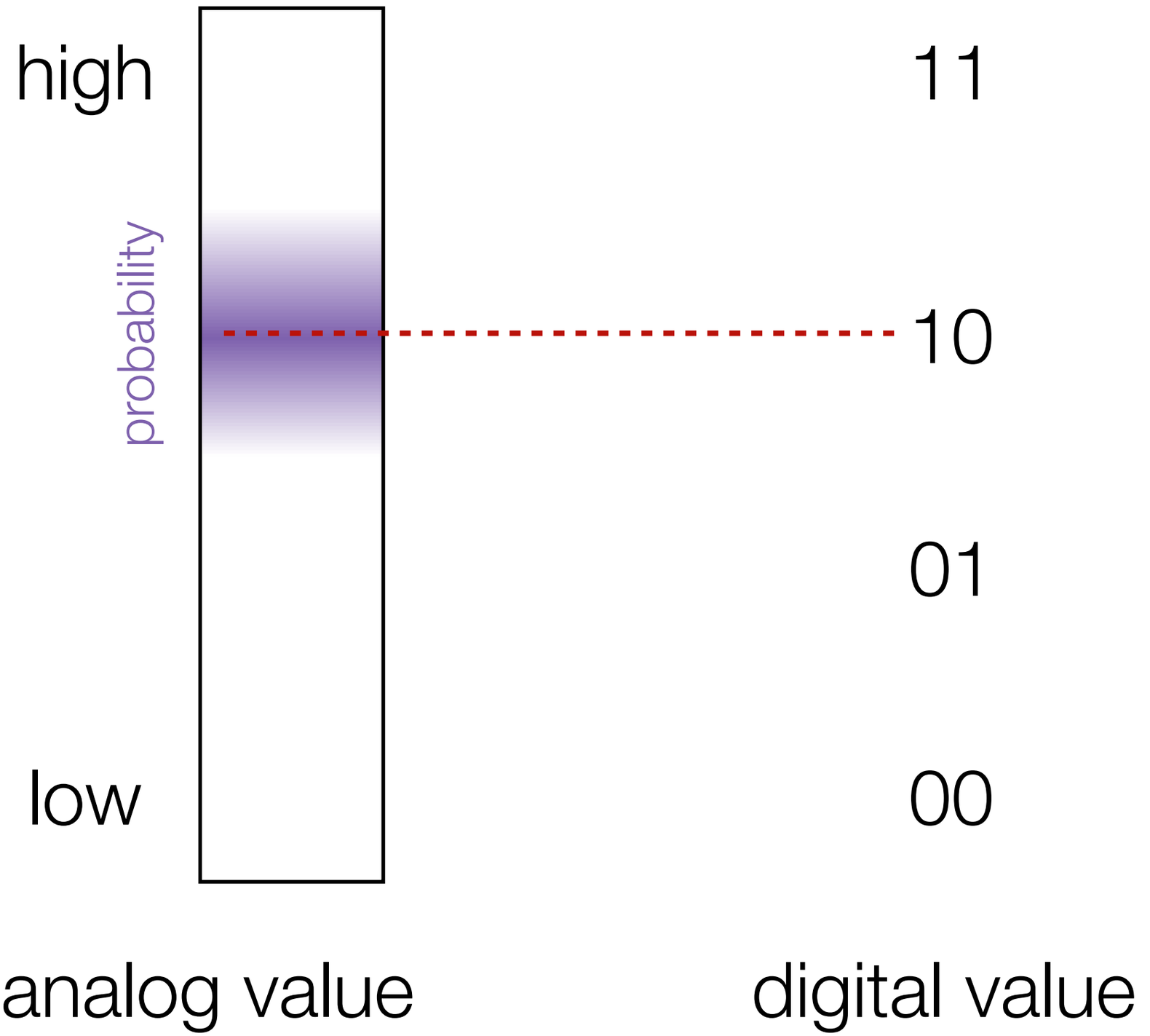
Single-level cells



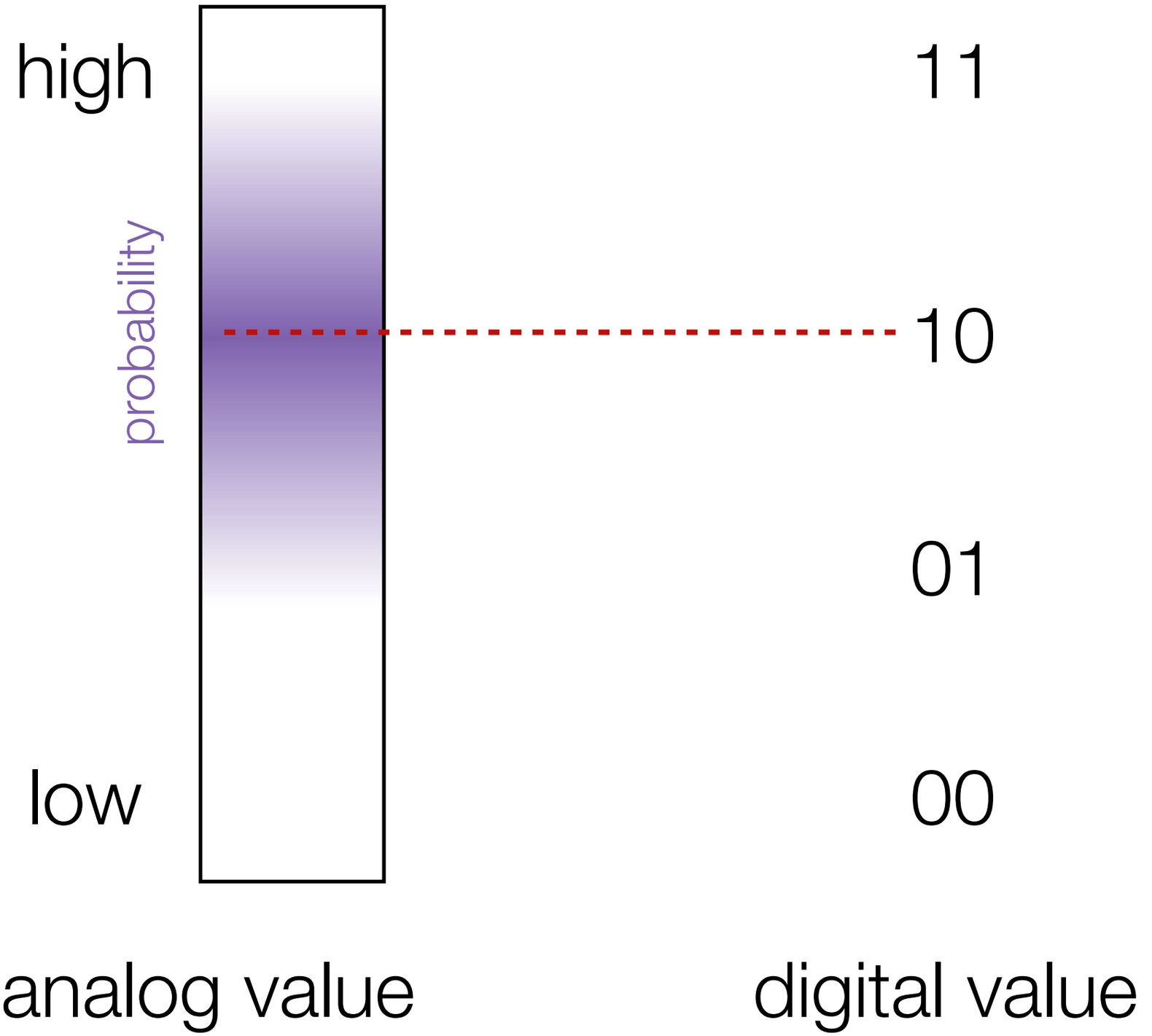
Multi-level cells

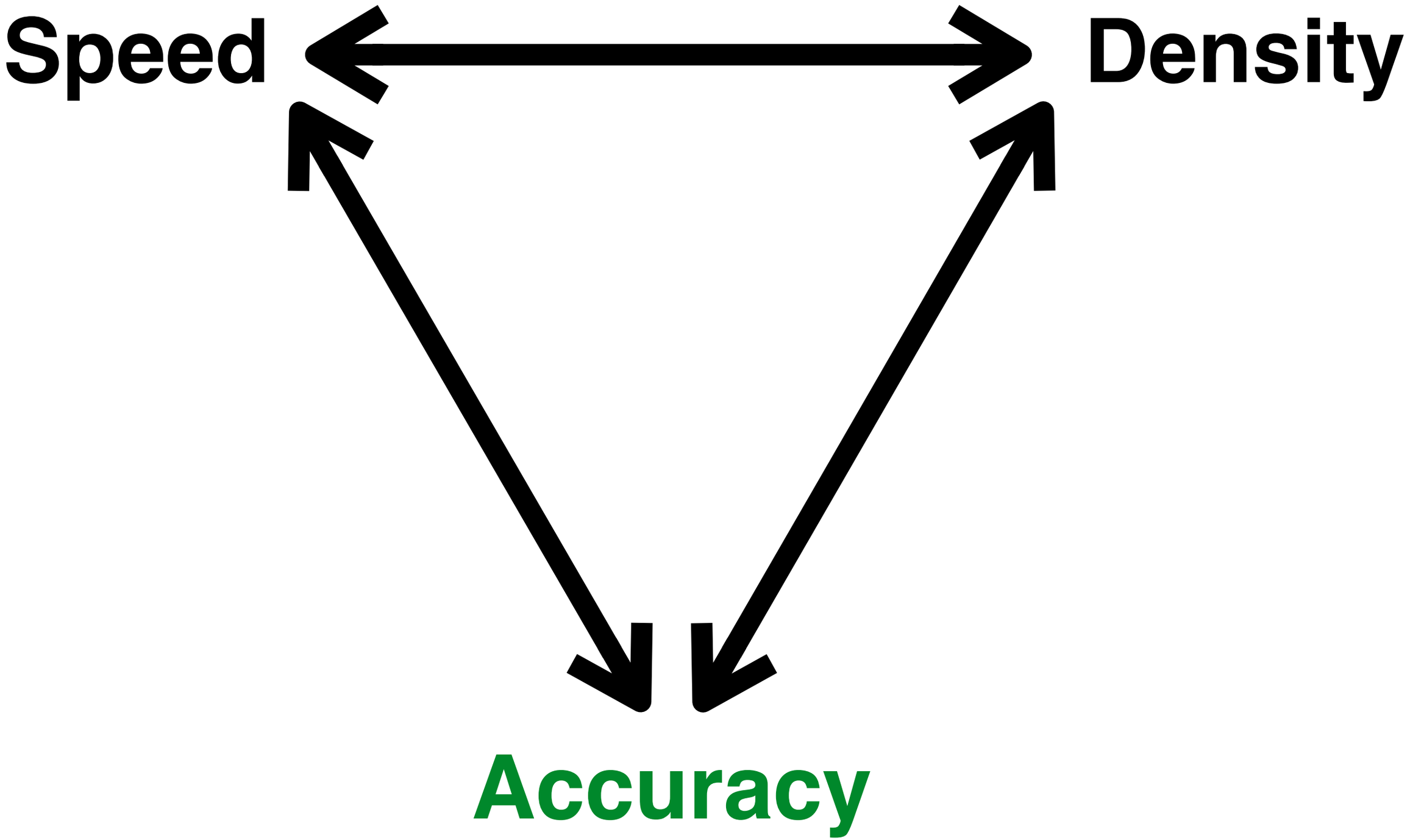


Writing to multi-level cells

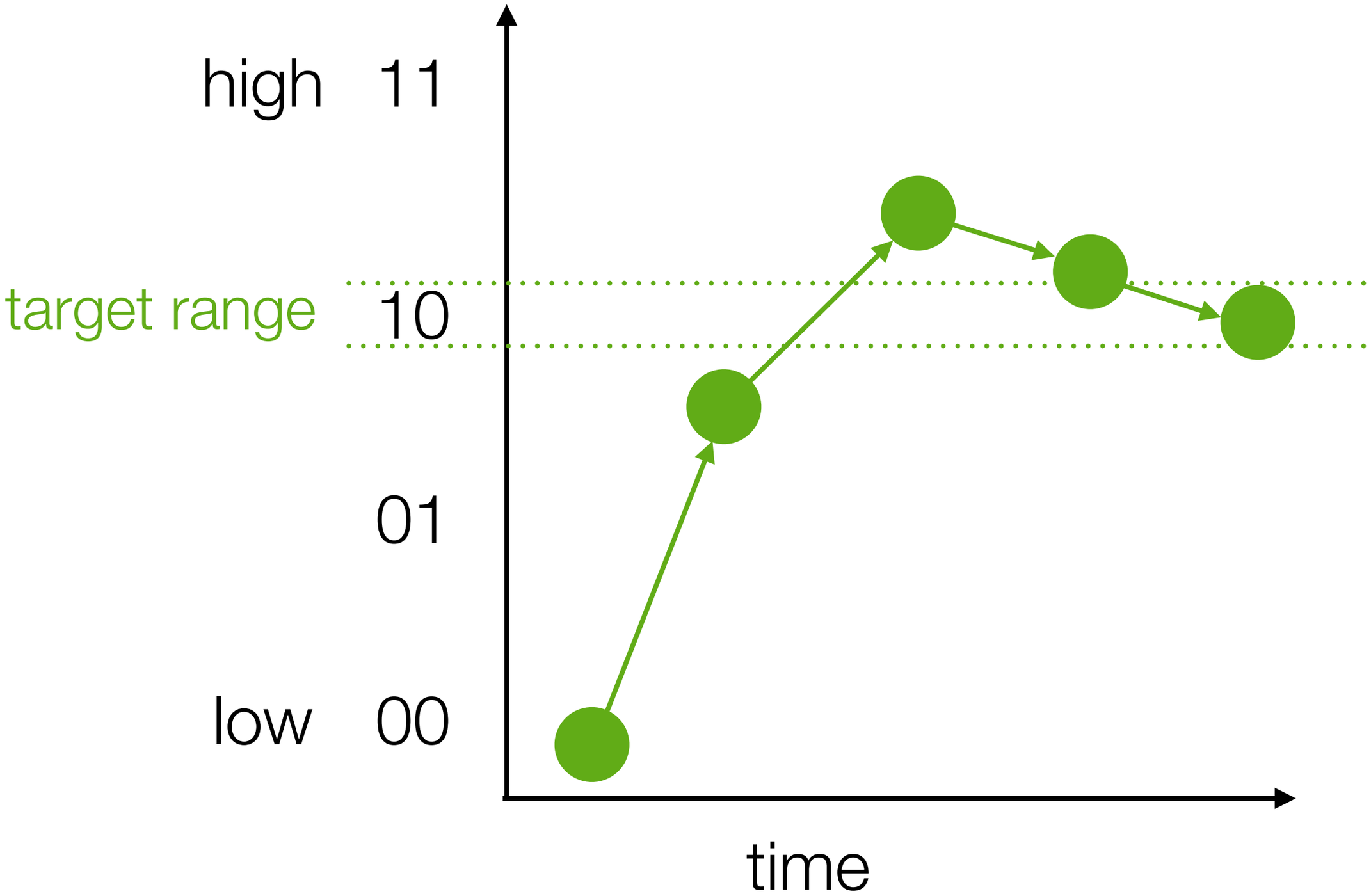


Writing to multi-level cells, approximately

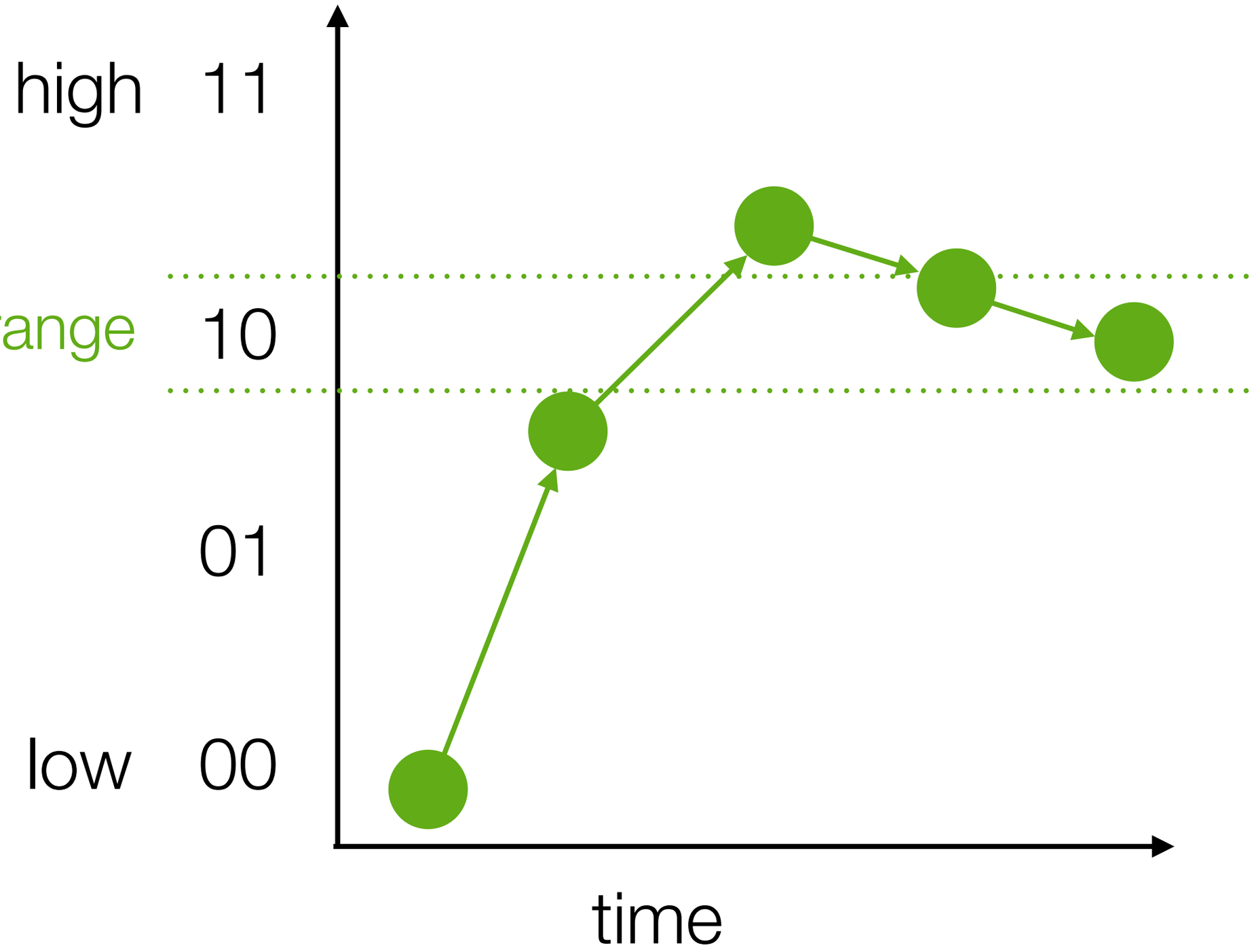



Speed
Density
Accuracy

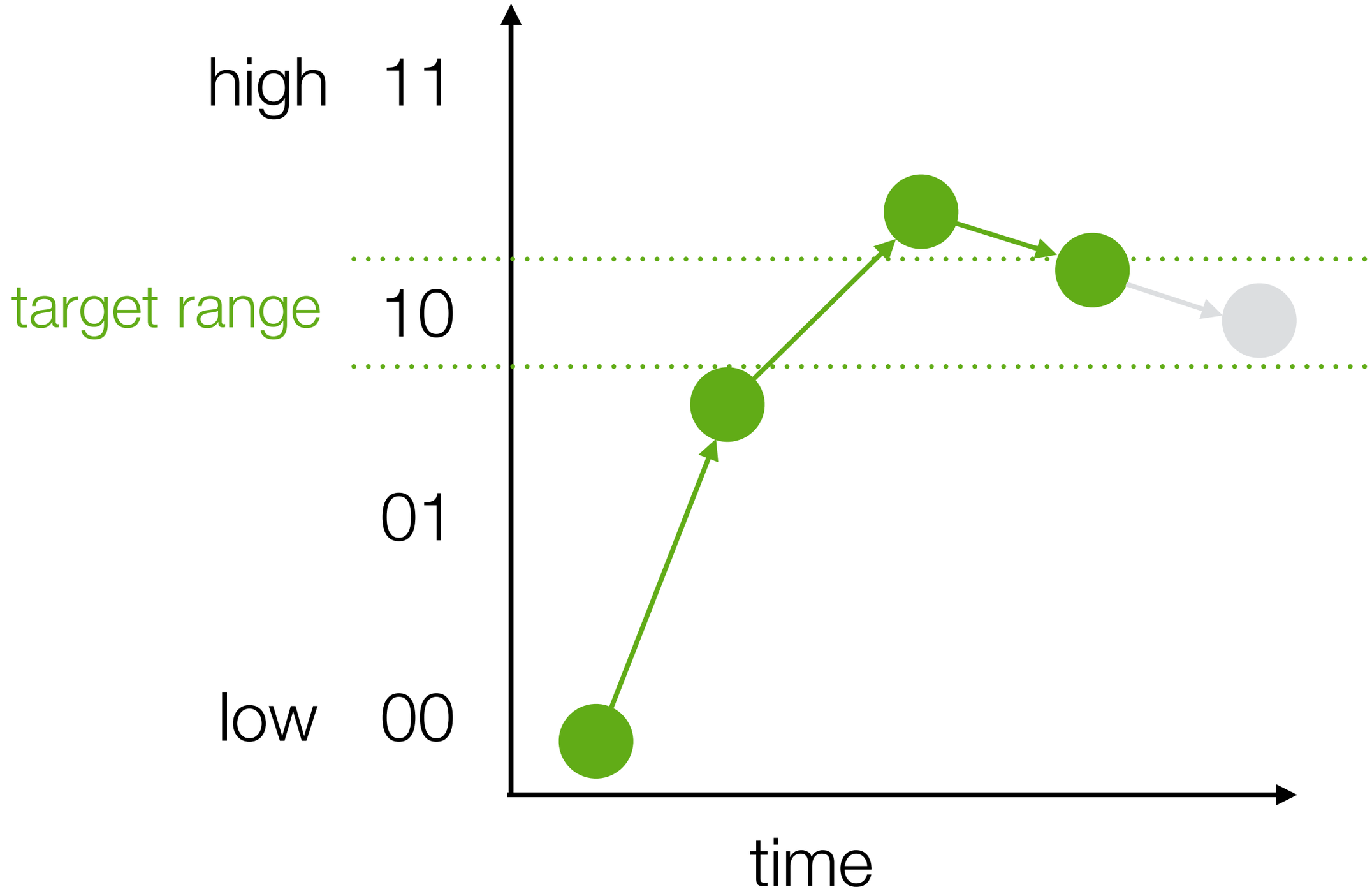
Iterative writes



Iterative writes, approximately



Iterative writes, approximately



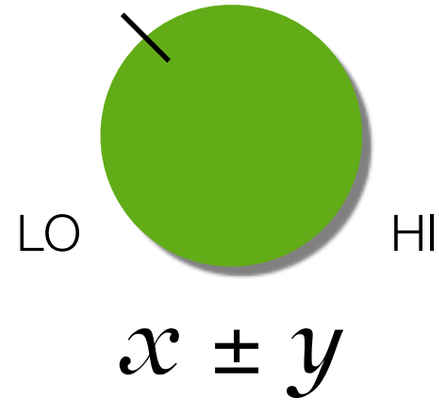
wider target range

fewer iterations to converge

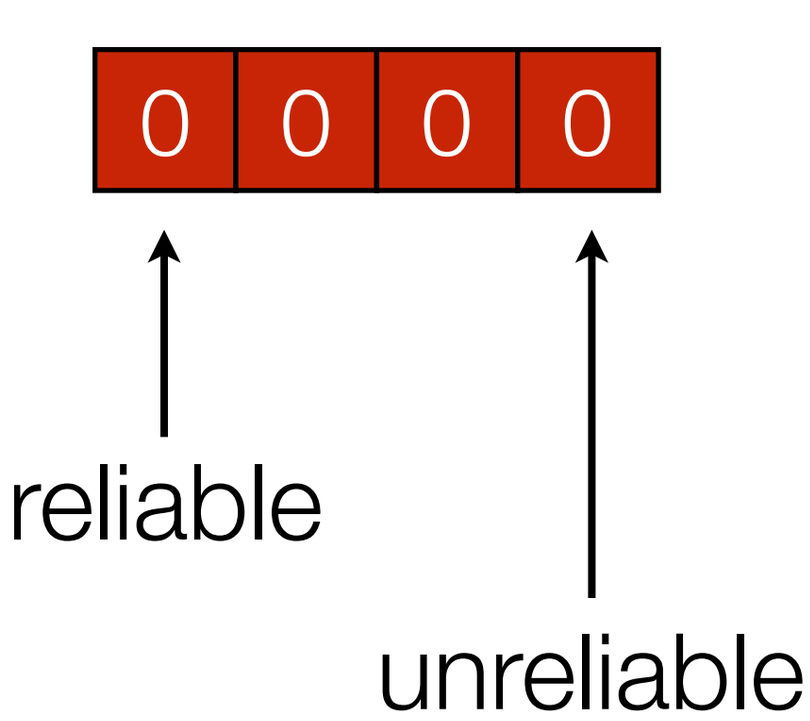
faster writes

(or better density at the same speed)

Encoding to minimize error in approximate MLC



1 cell, 4 bits



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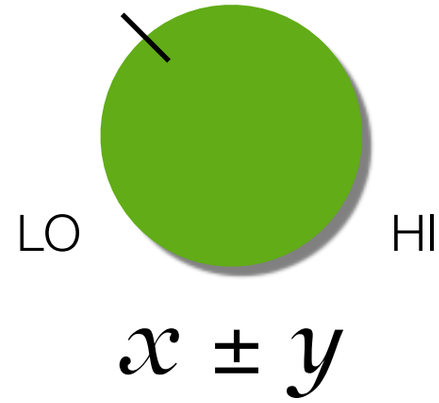
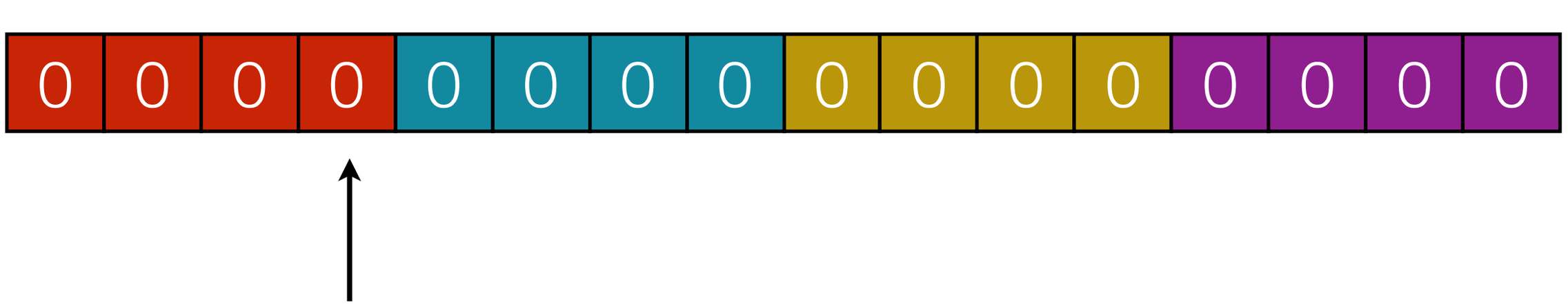
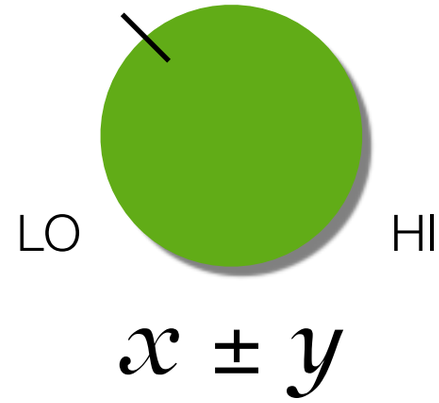


4 cells, 16 bits



lots of errors

Encoding to minimize error in approximate MLC



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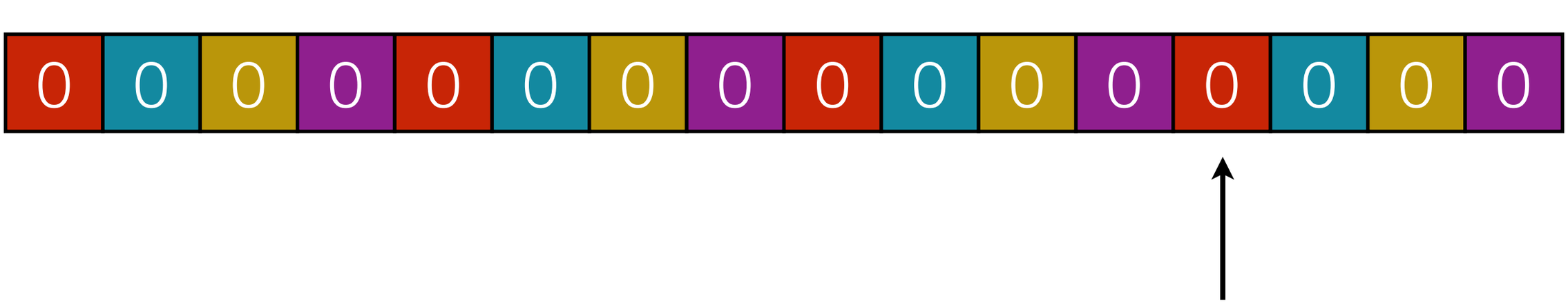
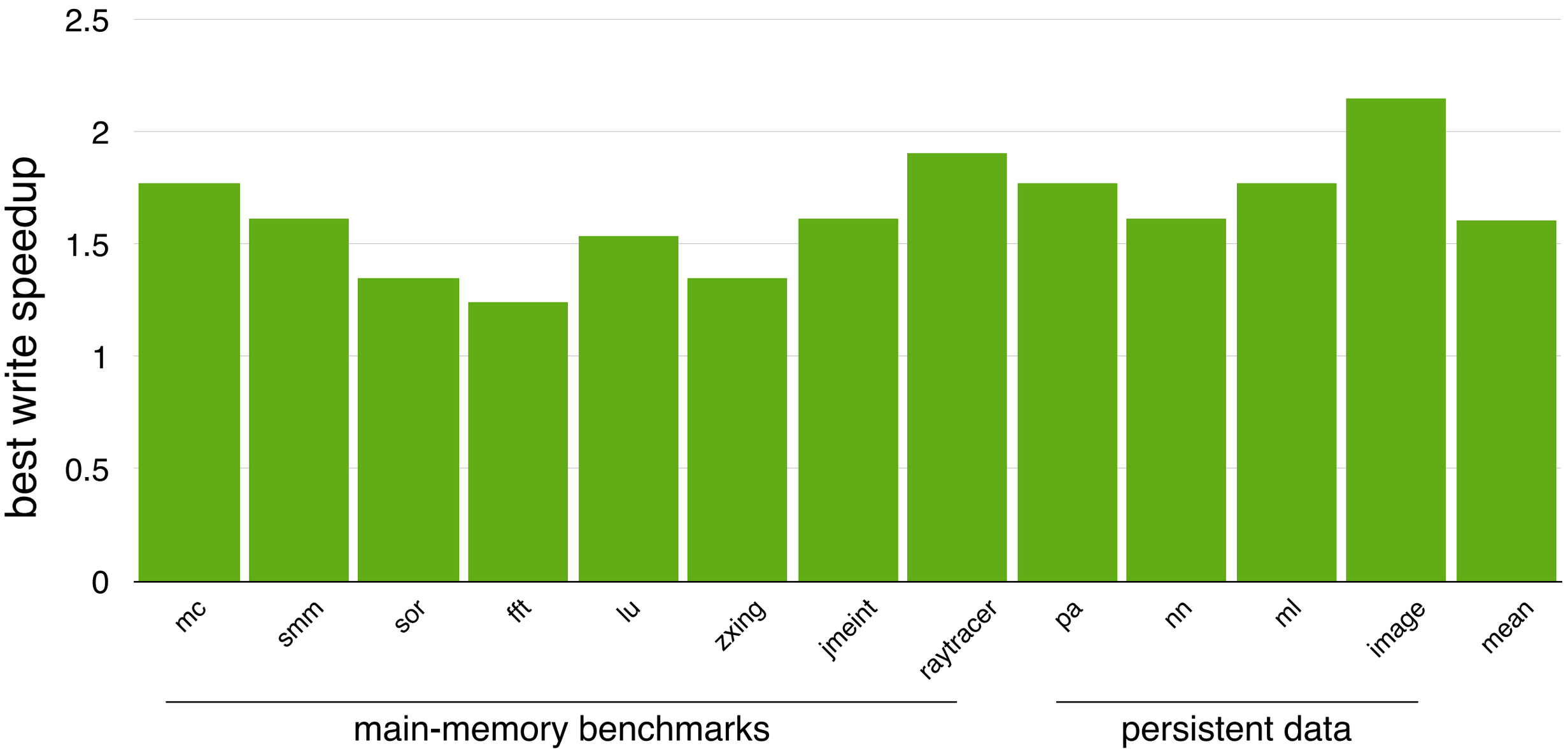


Write speedup for approximate MLC



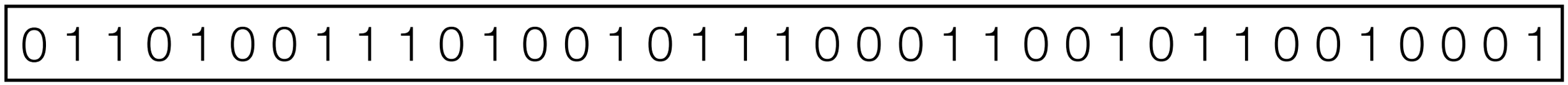
Writes are 1.7× faster on average
with quality loss under 10%

Approximate storage in PCM

Trade off performance in accesses.

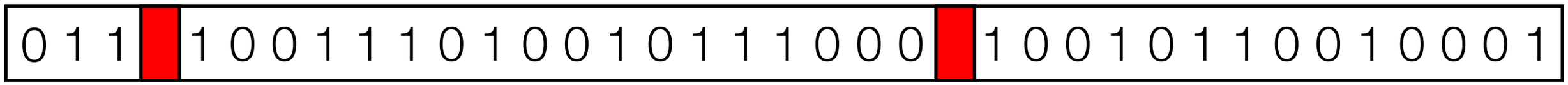
Use **worn-out** memory for approximate data instead of throwing it away.

Failed cells are a fact of life



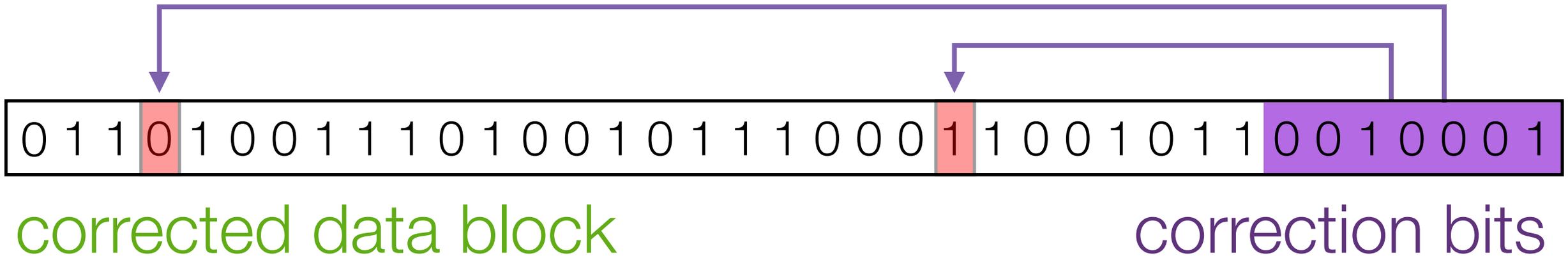
a good block

Failed cells are a fact of life

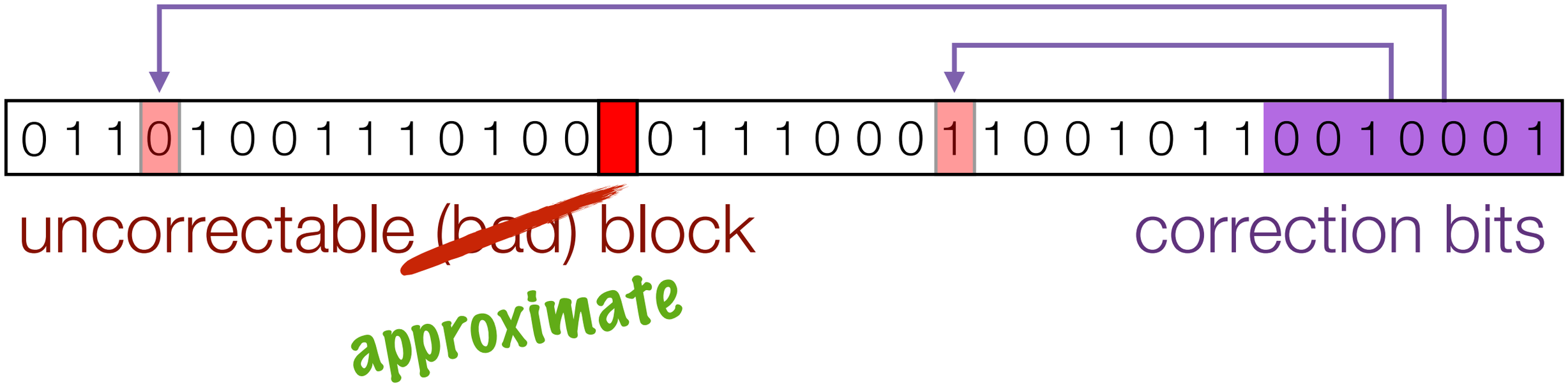


a (tragically) failed block

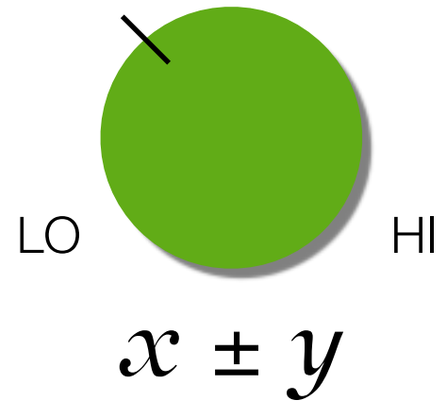
Traditional error correction

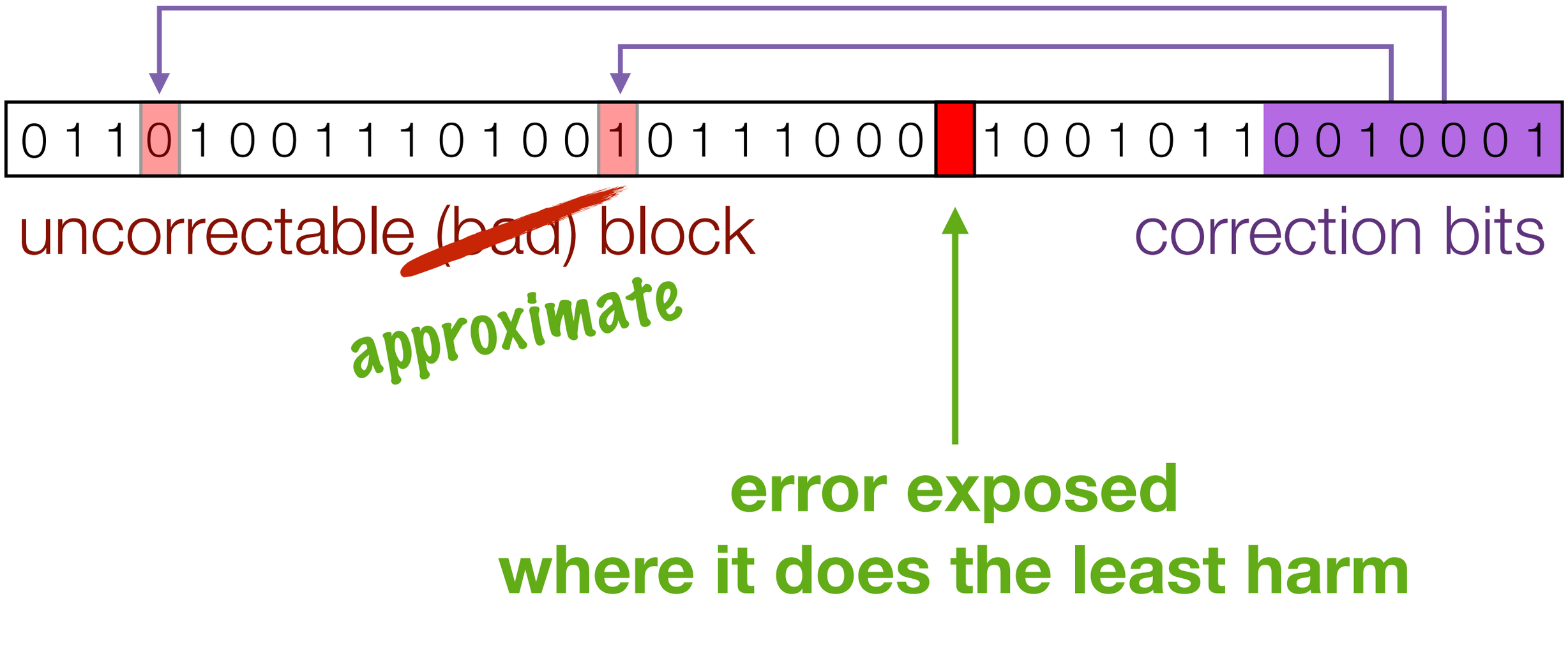


Correction resources are exhaustible

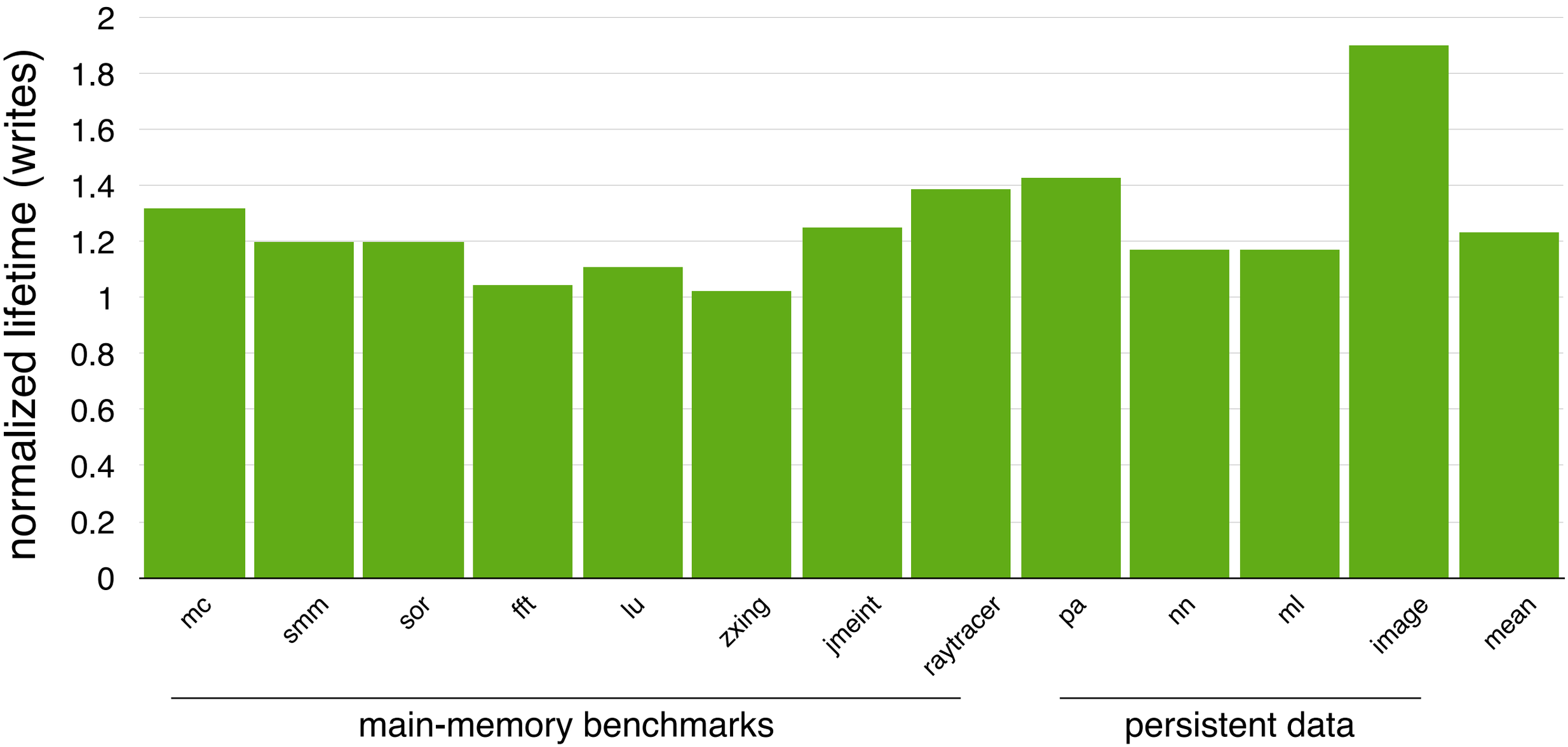


Prioritized error correction

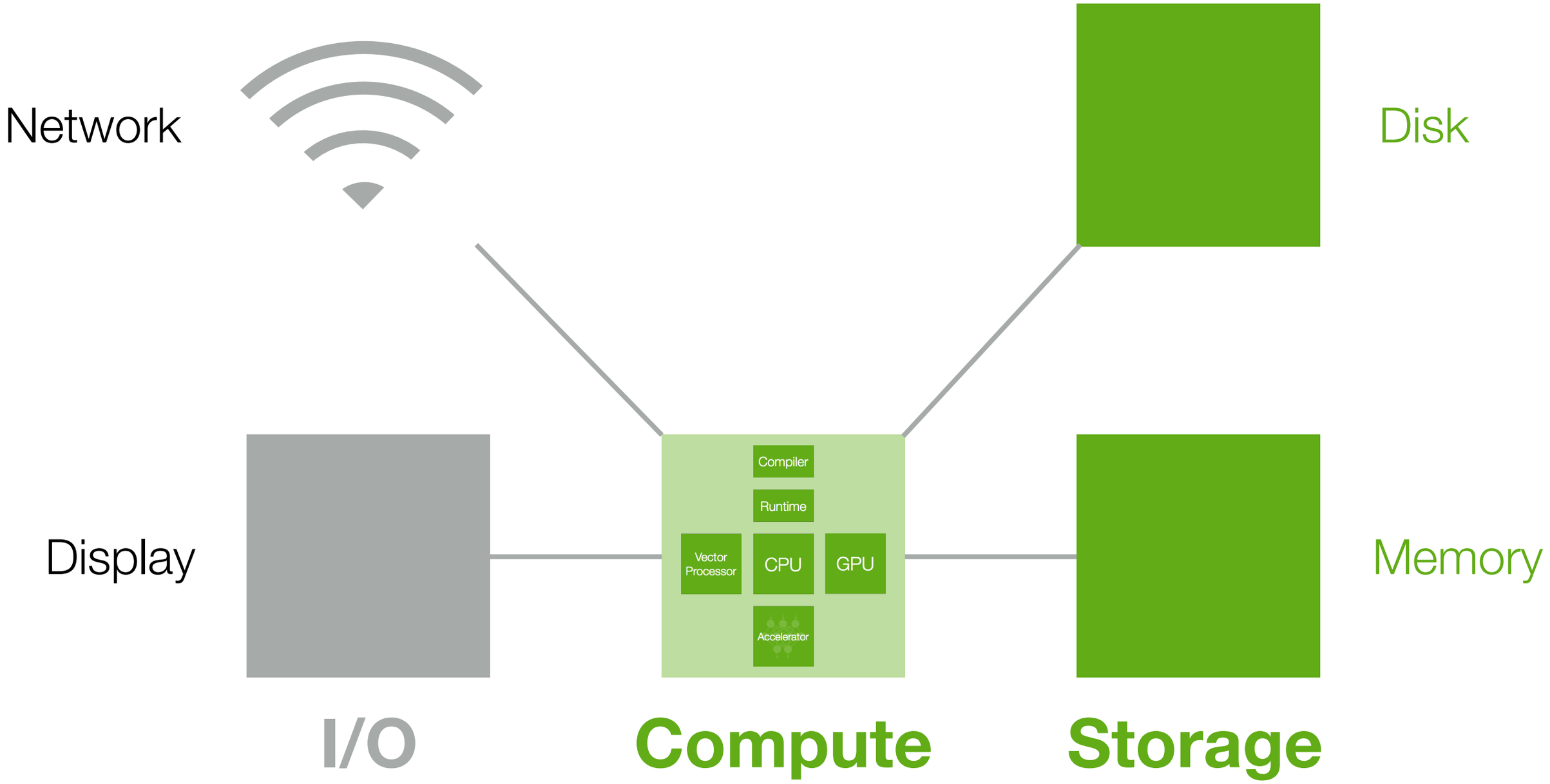




Lifetime extension with block recycling



Lifetime extended by 23% on average
or from about 5.2 to 6.5 years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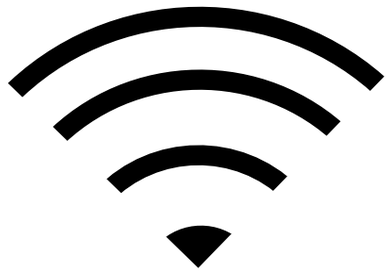
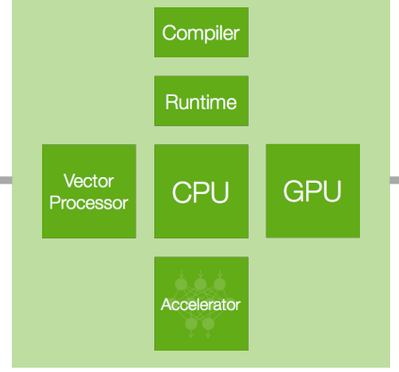
Network



Disk

Display



Memory

I/O

Compute

Storage