A Machine Learning Framework for NAND Flash Lifetime Extension

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A World of Machines… Learning

In the last few years, machine learning has become ubiquitous

Machine Learning

Deep Learning
- Machine vision
- Object detection
- ...

Data Analysis
- Time series analysis
- Regression
- ...

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The common approach today is:
Do you have a problem? Fix it with Machine Learning!
The “Devil” in Machine Learning

Using machine learning is not as simple as it appears…

• One of the biggest problems when using machine learning is neither the algorithm nor the implementation…

• “The problem is not the problem. The problem is how you define the problem…”
NAND Flash Memories Today

- 3D up to 96 layers
- 8 Tbits in a single BGA package
- Quad level cell (QLC)
- Circuits under array
- I/O bus @ 1200 MT/s
- $t_{PROG} \approx 3 \text{ ms}$
- $t_{READ} \approx 100 \mu\text{s}$
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- Cost per Gb $\approx$ HDD
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Reliability!!
NAND FER fighting against the Shannon limit
NAND Flash

- The higher the data reliability, the longer the device’s lifetime (and the cheaper the solution…)
- Problem statement: increase data reliability to extend NAND flash’s lifetime

…Now what?…
3D NAND Flash Memories

Having a deep understanding of the device’s physics is the only way to get good data reliability

• 3D NAND flash is a stack of multiple memories
• Array architecture
• Cell-to-cell variability
“…Welcome to the jungle…”

Many parameters impact NAND flash reliability including soft info, code-rate, cycling speed, and temperature.

- Too many parameters to look at
- Too many possible correlations
- Too many features

There is no guarantee that we’ll find the best setting for each working conditions…
Problem? Use Machine Learning

NAND flash know-how + Machine learning know-how

...Now what?...

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R. Micheloni (ed.), 3D Flash Memories, DOI 10.1007/978-94-017-7512-0_3

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* Rino Micheloni, 3D Nand Flash Memories, Springer 2016
Goals

What do we want to achieve?

• A framework able to test which parameters impact the reliability of a NAND flash (and which parameters do not)
• An framework able to tune these parameters depending on the reliability target
• Output: An algorithm (model) able to learn how to enhance the reliability in a completely agnostic and autonomous way → Machine Learning!
• Remember, we are looking for a framework and not an algorithm! The algorithm is just the output of the framework.
• Characterization of NAND flash memories
• Brute force testing of thousands of different machine learning algorithms
  • Create a software model of the target algorithms
• Implement best candidate algorithm at firmware level
• Hardware acceleration

• Test with NVMe Flashtec™ controller
Firmware to hardware latency gain ≈ 100x
“...a strategic inflection point is a time in the life of business when its fundamentals are about to change. That change can mean an opportunity to rise to new heights. – Andy Grove”
Conclusions: M$^2$ZC Conjecture

“In hyperscaled NAND flash memories each layer will be optimized by machine learning”

- **Takeaway #1**: Does machine learning work with NAND flash memories? → Yes!
- **Takeaway #2**: Are humans obsolete? 
  → Don’t think so! We still need to guide the machine (a student can learn at a much faster rate with a good teacher…)

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Thanks

Q&A

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