Machine Learning based Digital Signal Processor for NAND Flash Storage System

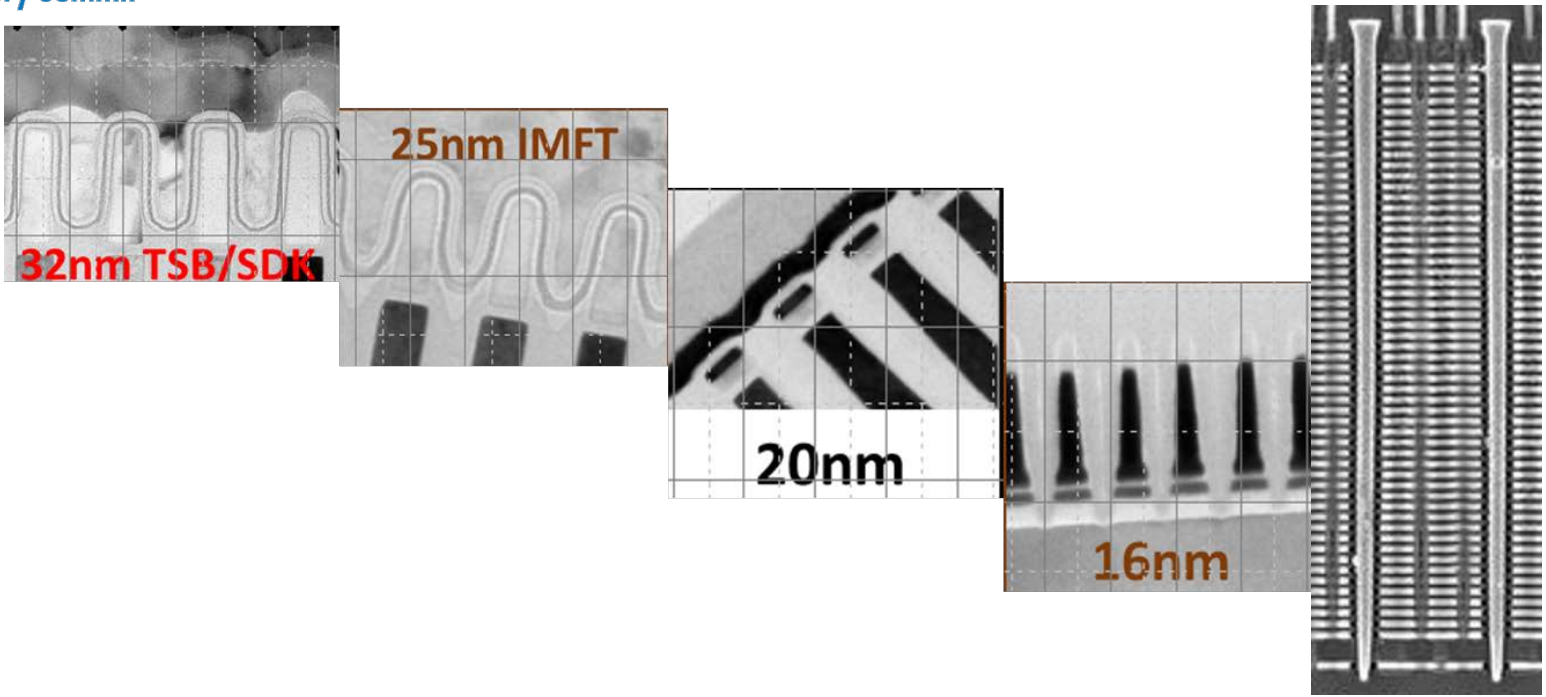
Wei Lin

Senior Architect / Manager / PHISON Electronics Corp.

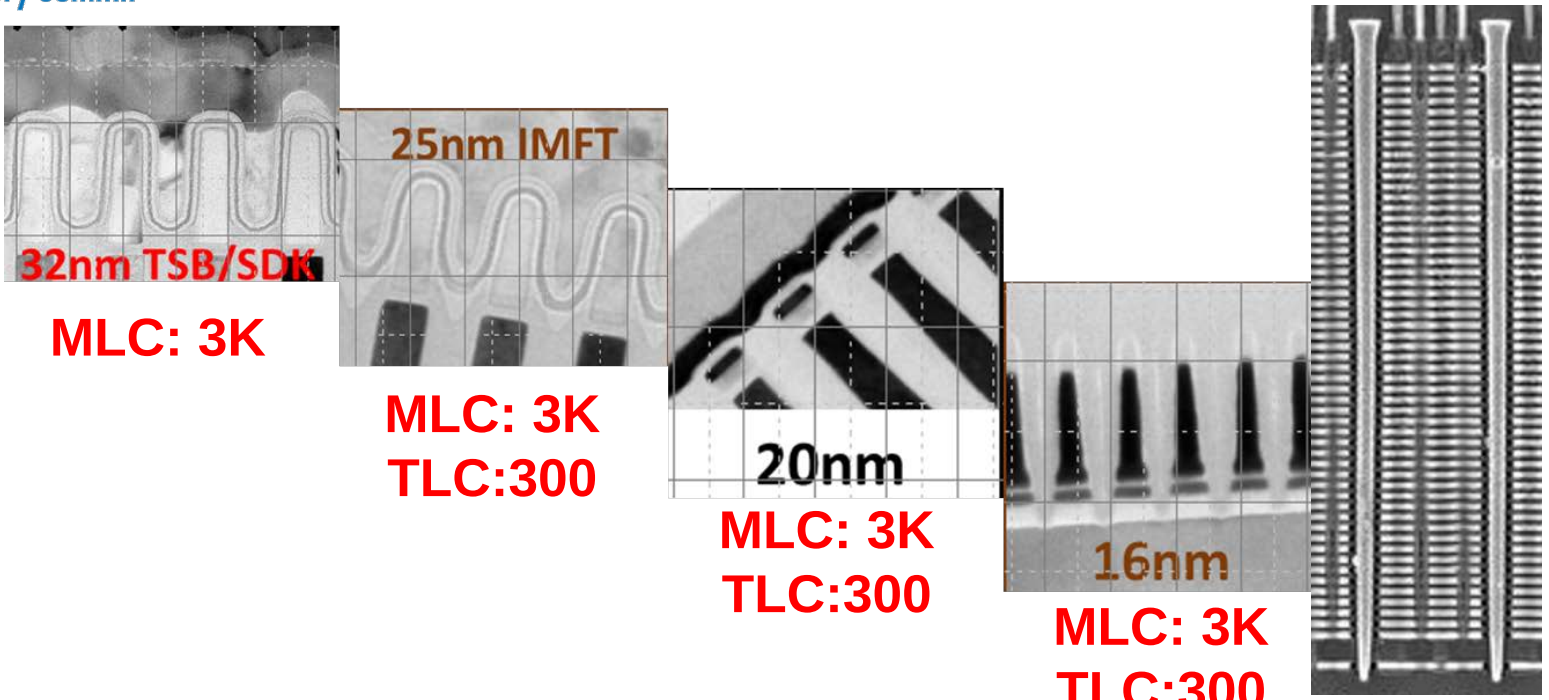
CTO / CoreStorage Electronics Corp.

wei_lin@phison.com

Evolution of NAND Flash memory



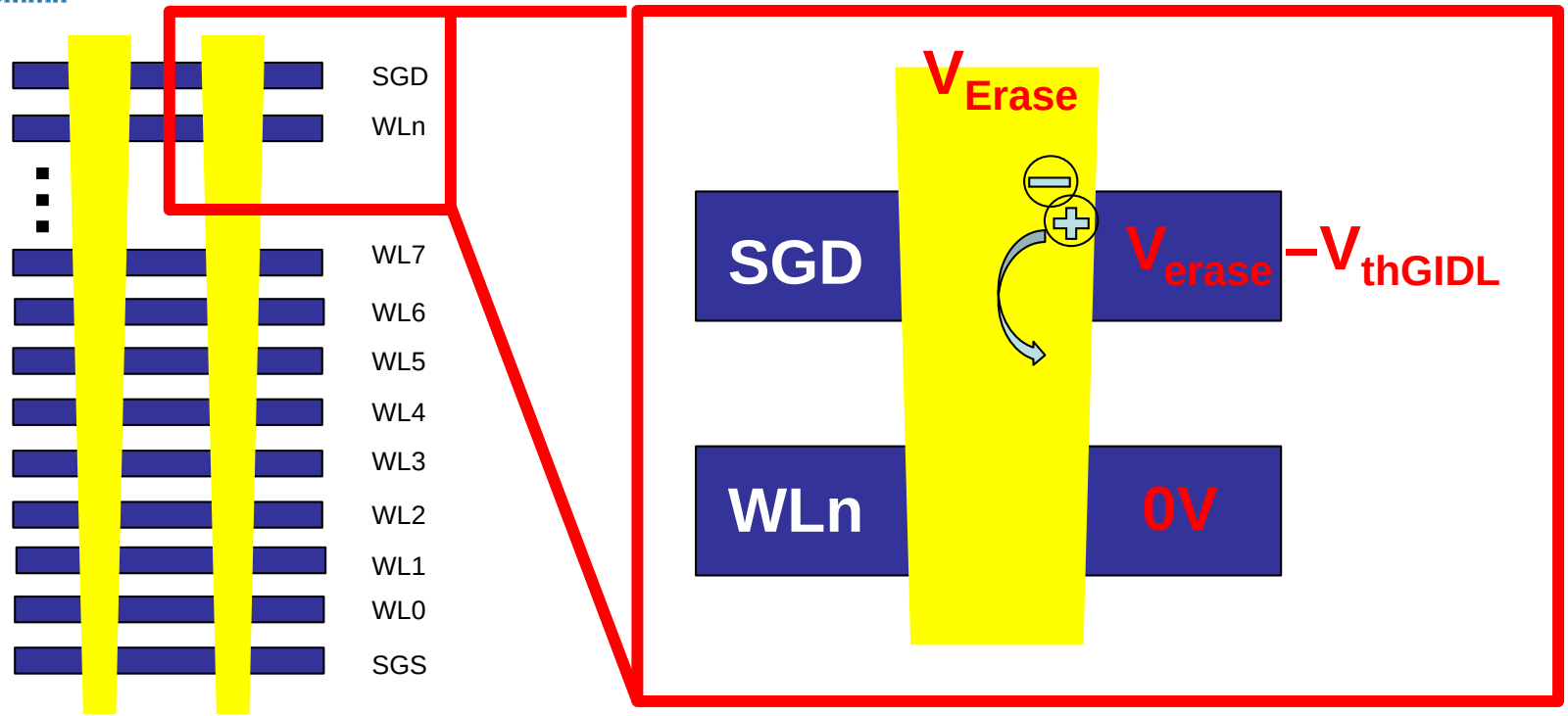
Evolution of NAND Flash memory



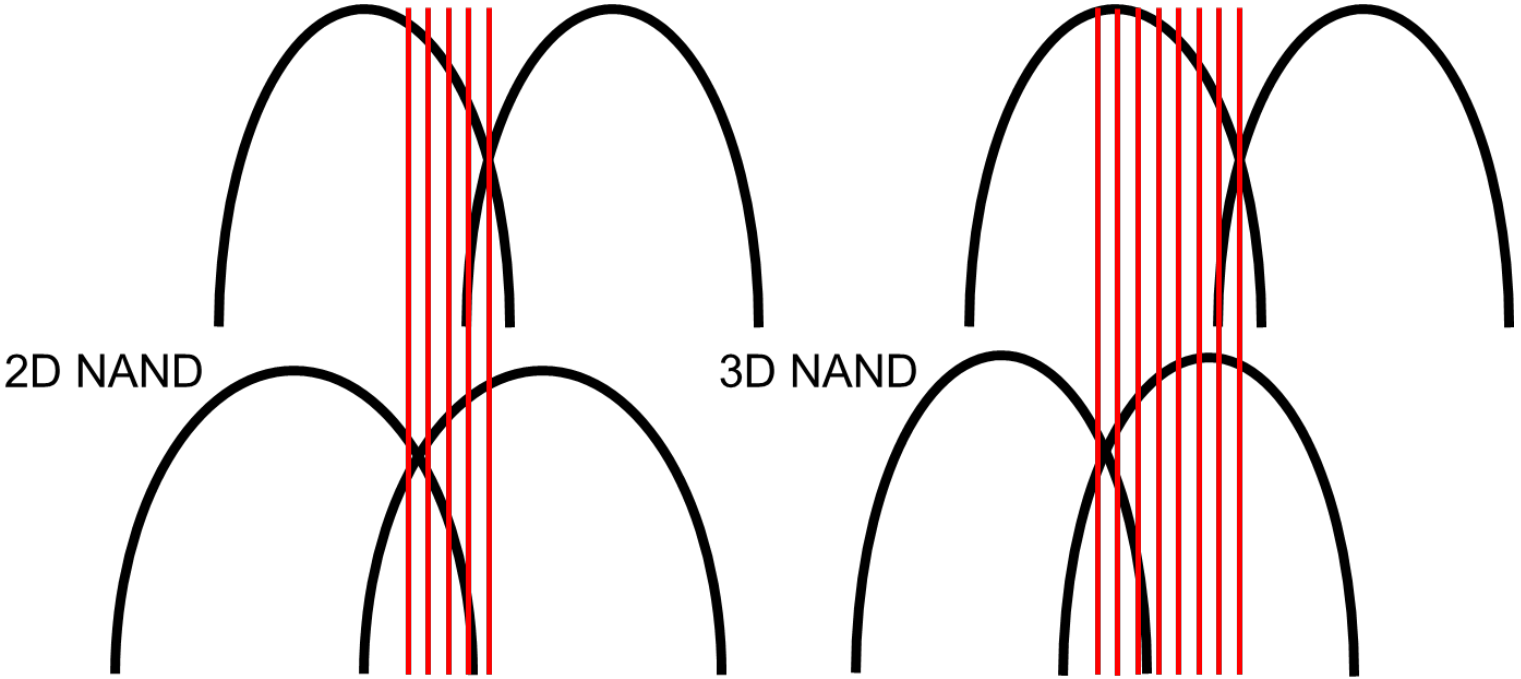
Reliability Cruxes of 3D NAND Flash

- Redistribution of Electrons
- Erase Mechanism
- Larger Charge Loss Probability, Less Deviation
- Layer Dependency
  - Uneven Erase Distribution
  - Uneven Read Disturbance
  - ……

Erase Mechanism of 3D NAND Flash

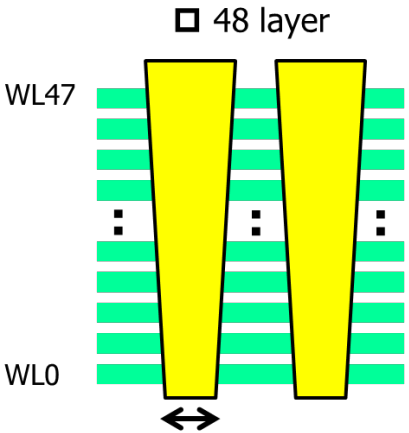


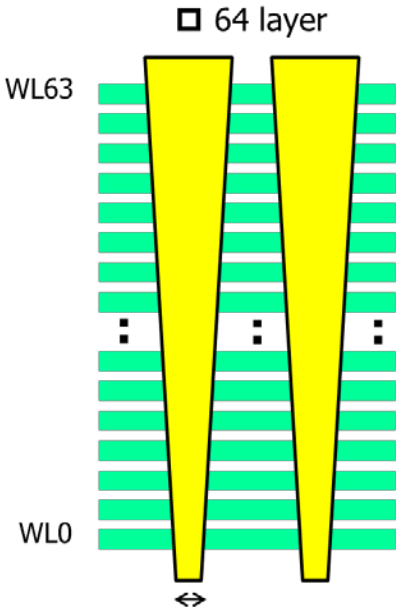
Decoding Latency Increases form 2D to 3D

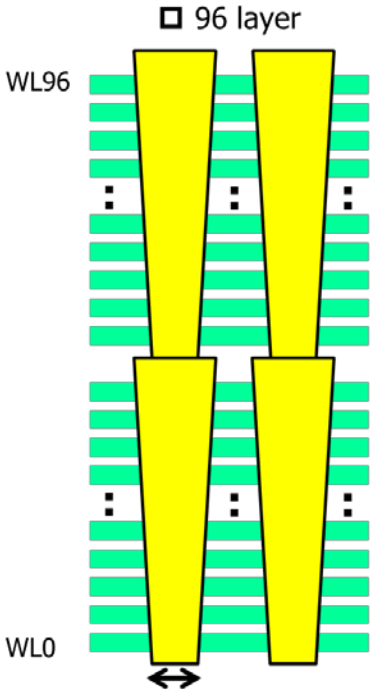


Layer Dependency of 3D NAND Flash

- Memory Hole Etching
  - Memory hole: taper shape

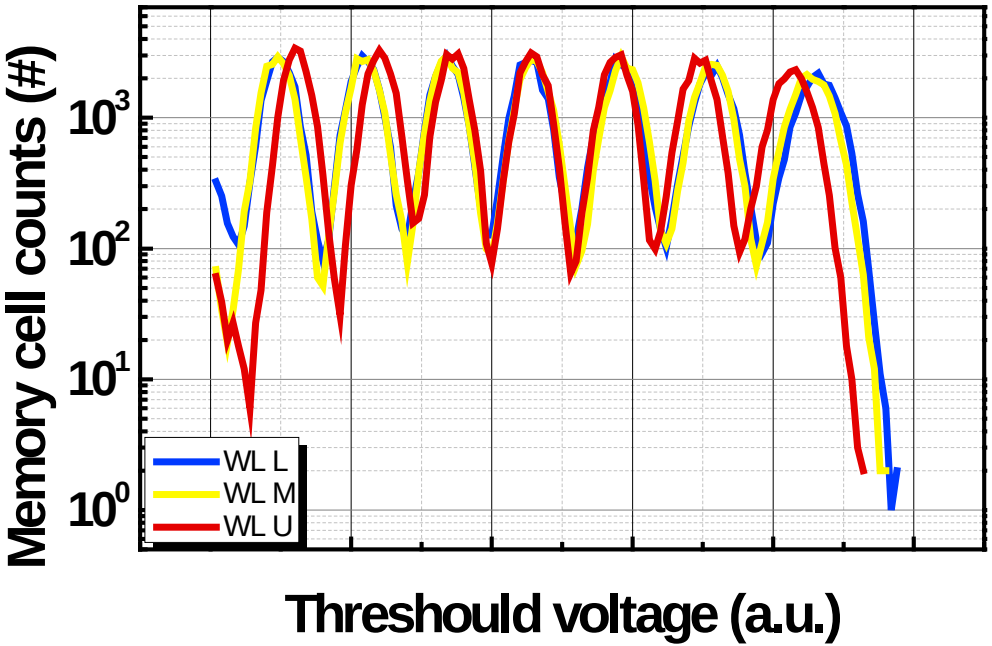


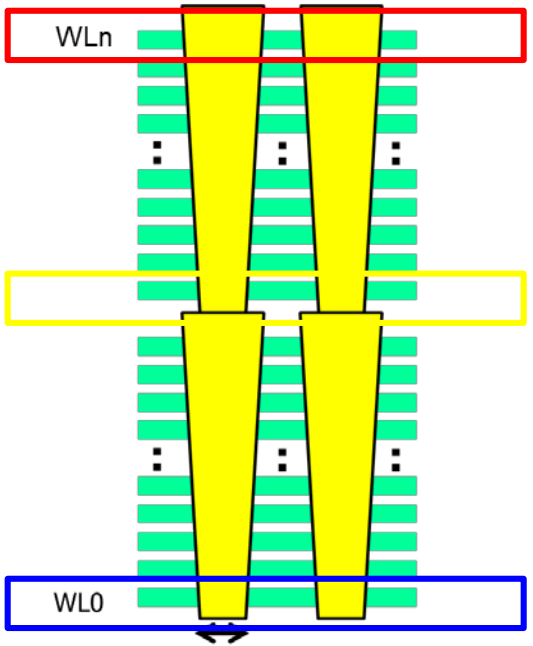




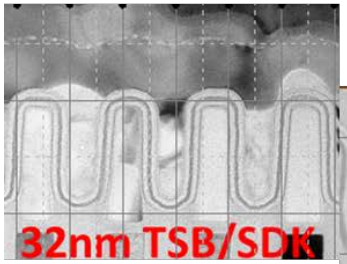
➢ Aspect ratio become lager with etching depth increase.

Layer Dependency of 3D NAND Flash

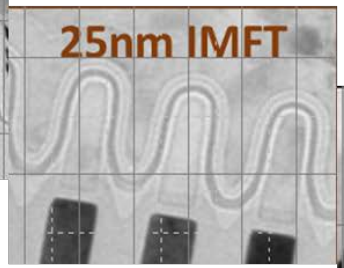




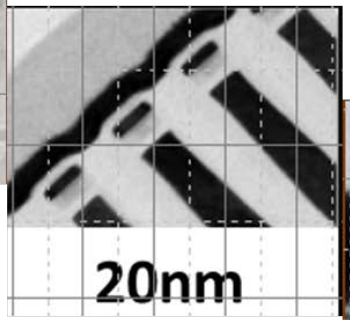
The Reliability is not Free



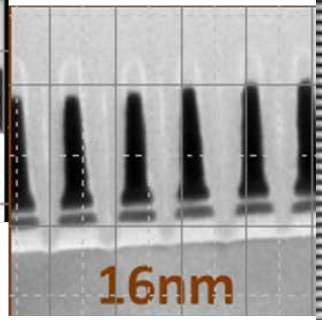
MLC: 3K
BCH



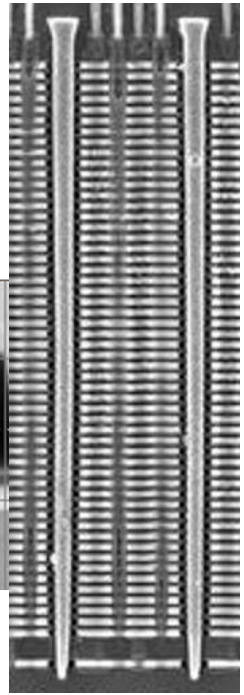
MLC: 3K
TLC:300
BCH+RR



MLC: 3K
TLC:300
BCH+RR



MLC: 3K
TLC:300
BCH+RR



TLC: 3K
LDPC+RR

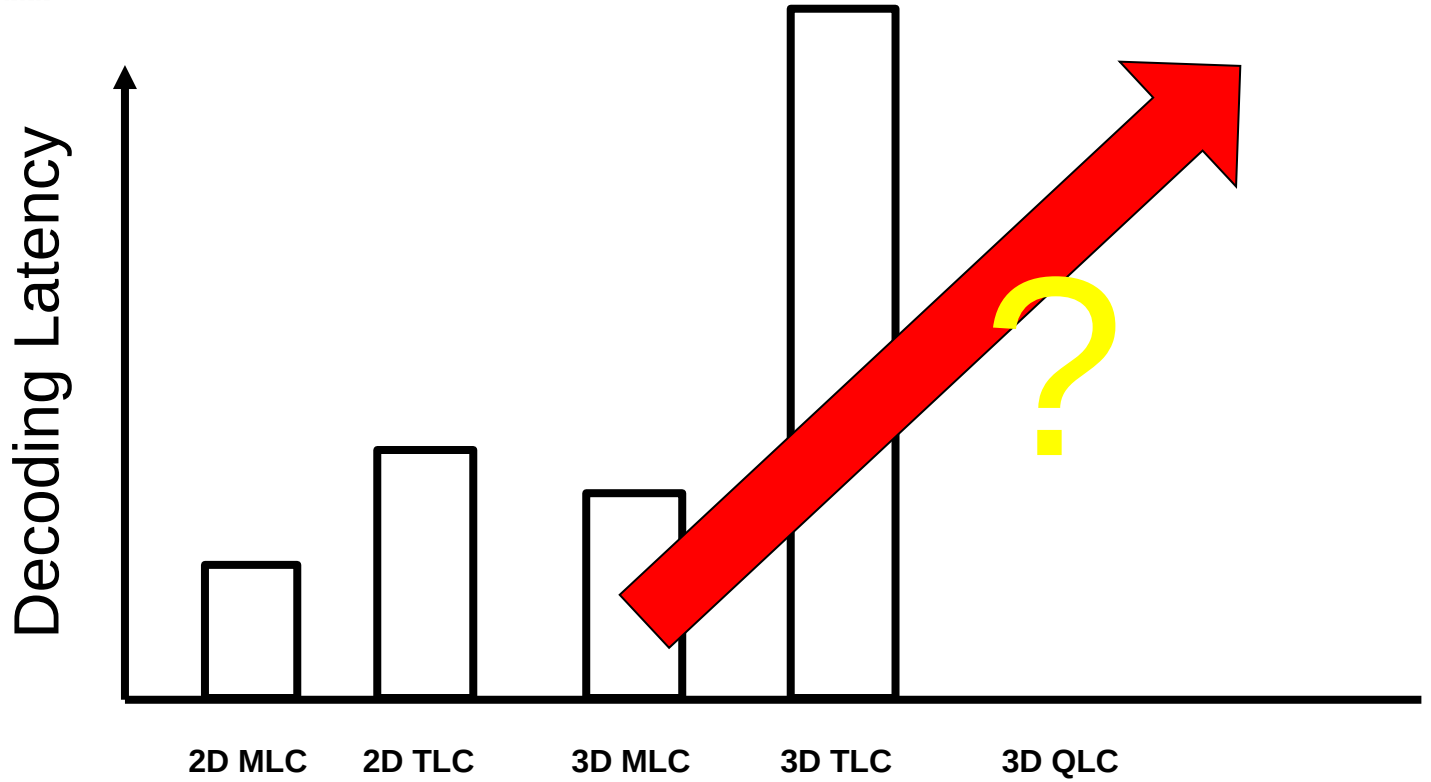
Even we have LDPC……

- Should we still use Read Retry?
- Extra Information for decoding
- Opti. Read Level & Vth distribution / LLR mismatch
- HRE
- Cost
- Power consumption

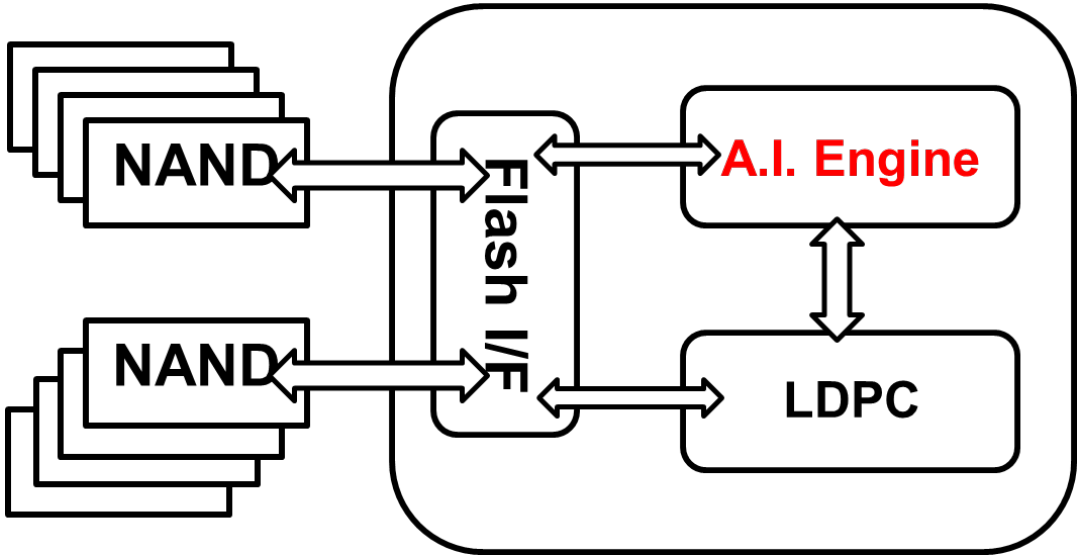
Even we have LDPC……

- Should we still use Read Retry?
- Extra Information for decoding
- Opti. Read Level & Vth distribution / LLR mismatch
- HRE
- Cost
- Power consumption

Evolution of Decoding Latency



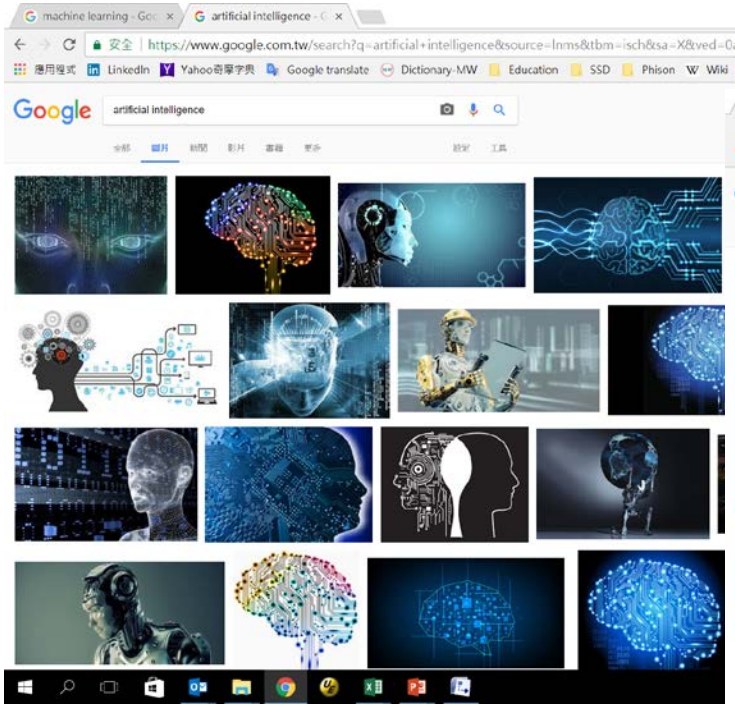
DSP Based on Machine Learning

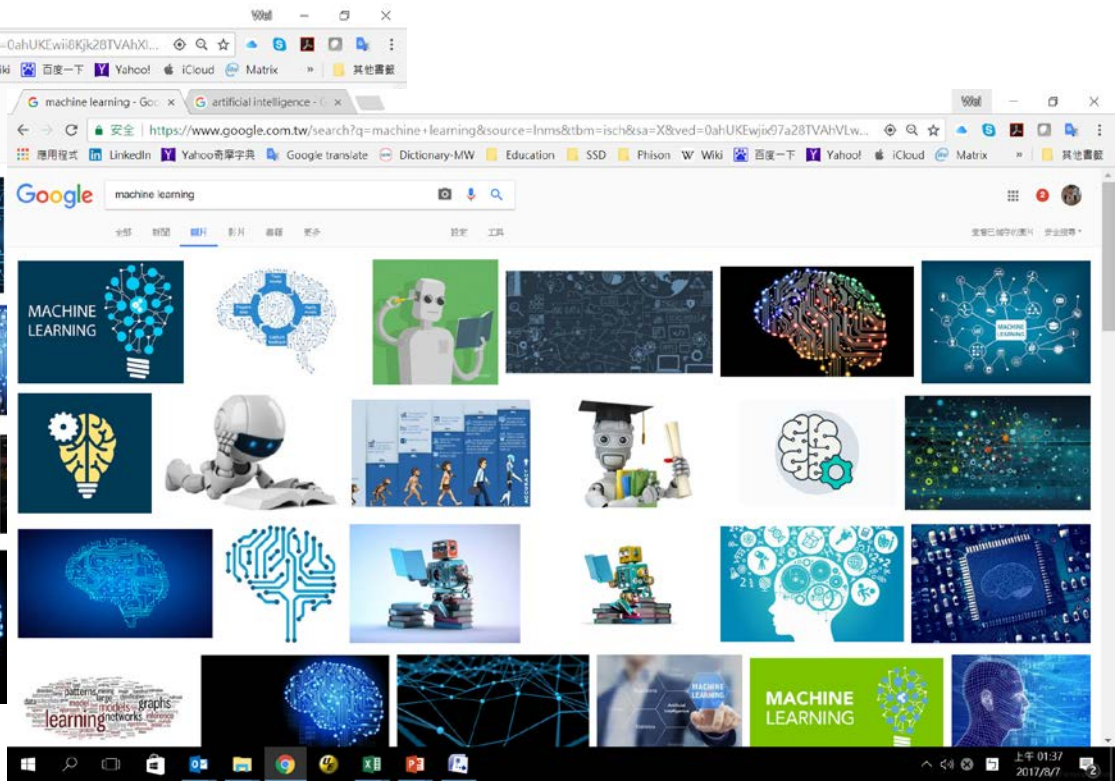


- Only few retry table
- No need soft information
- Reach the theoretical correction capability of LDPC
- As the Same as 2D NAND

➢**DSP engine makes the decoding flow of LDPC as simple as BCH**

What is Artificial Intelligence (A.I.) ?

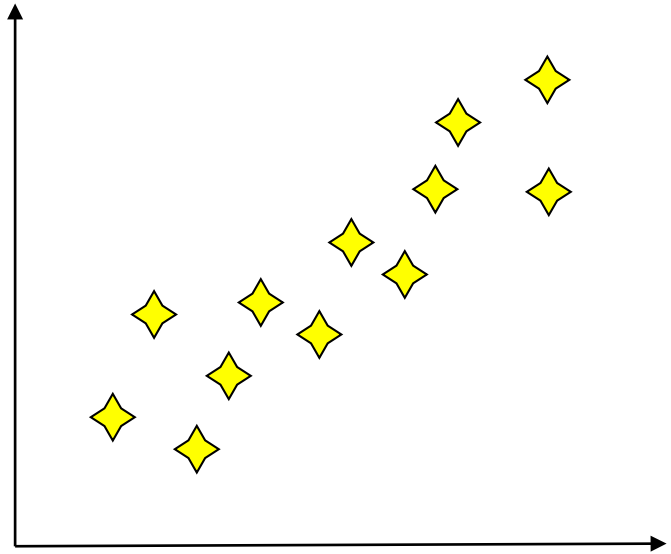




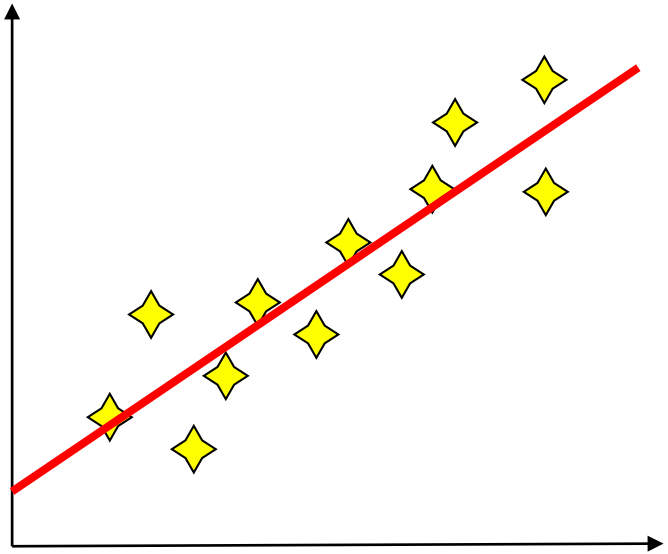
Artificial Intelligence

- Any function generation.
  - $f(picture) = \{\text{"cat","dog","monky"}\}$

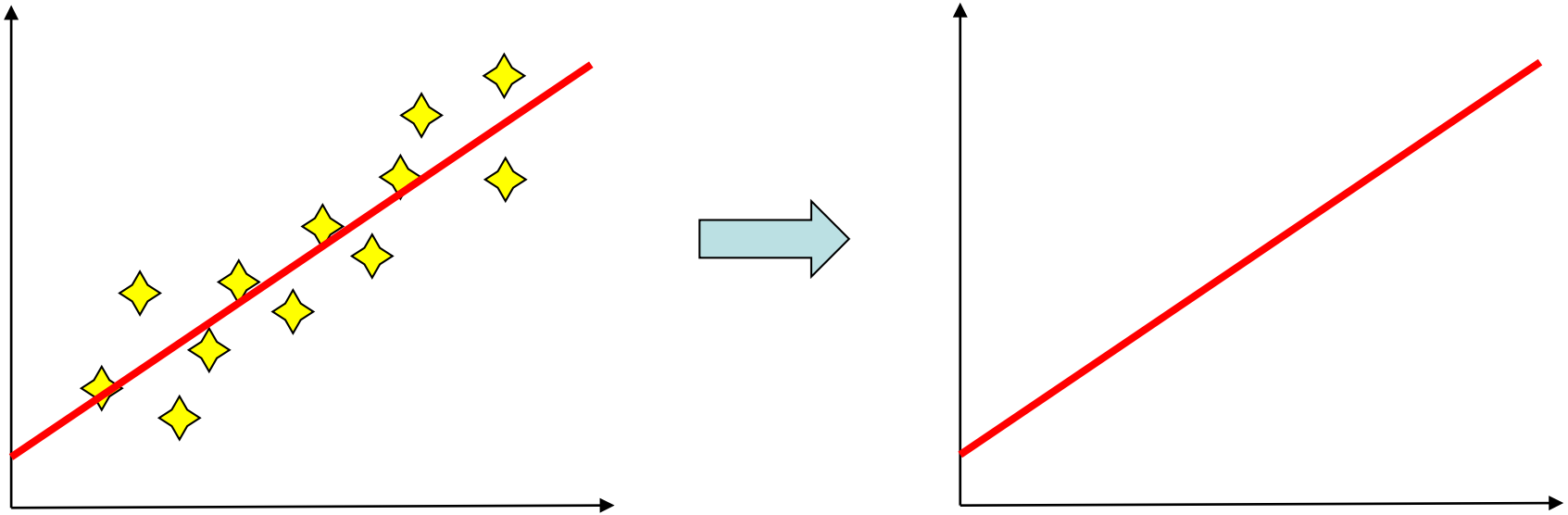
What's Machine Learning?



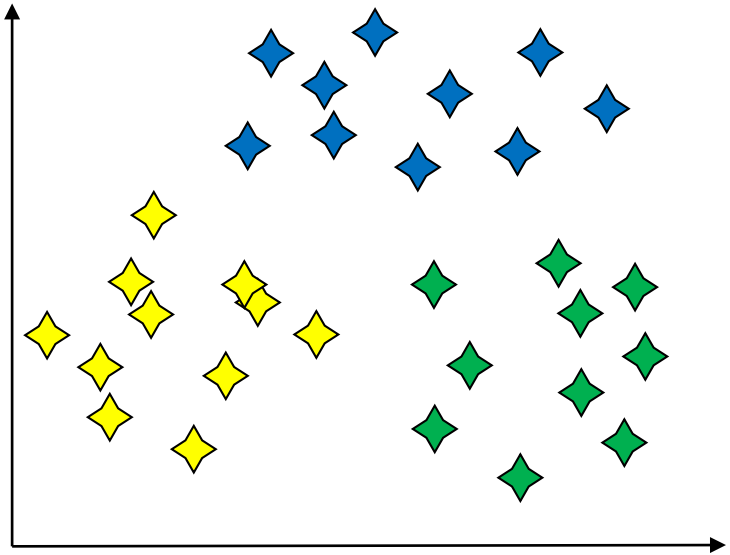
What's Machine Learning?



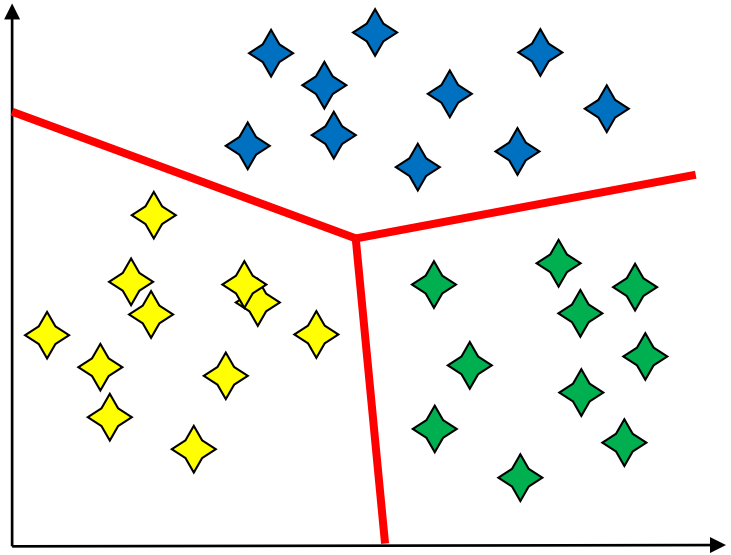
What's Machine Learning?



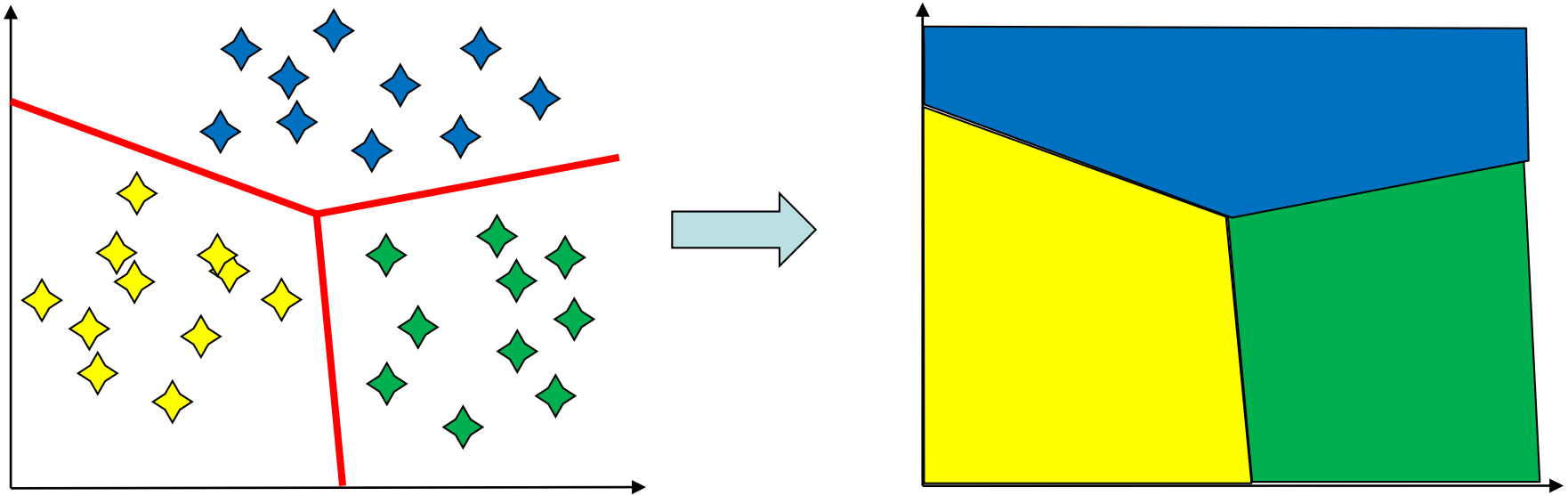
What's Machine Learning?



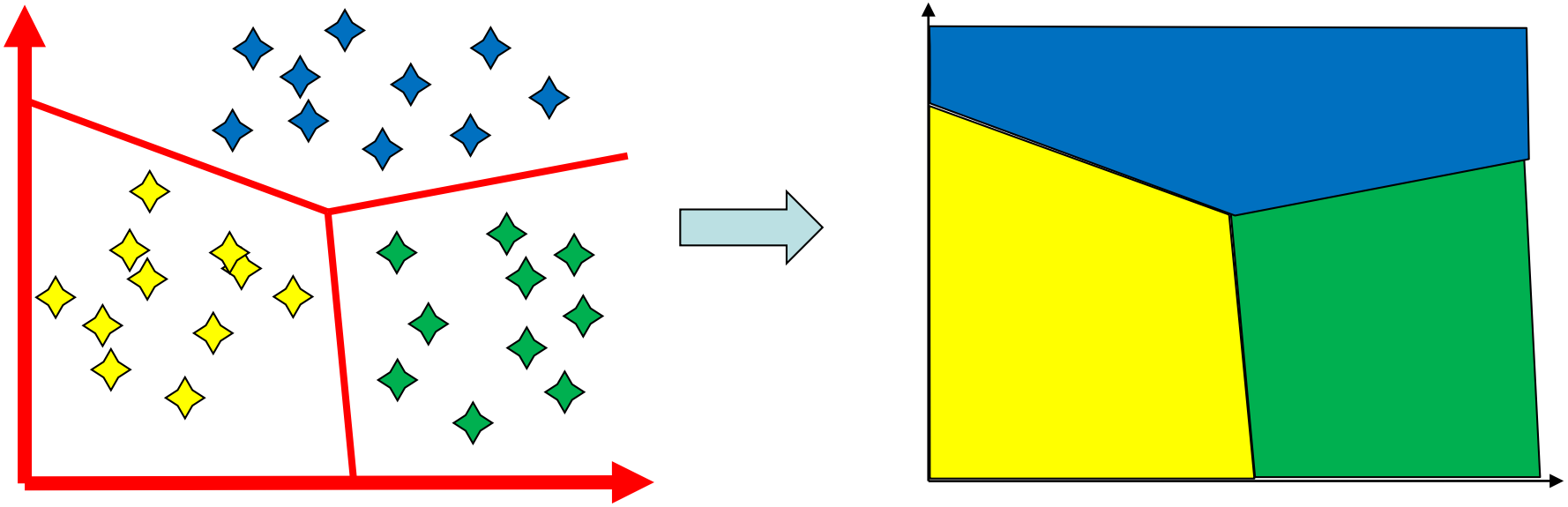
What's Machine Learning?



What's Machine Learning?



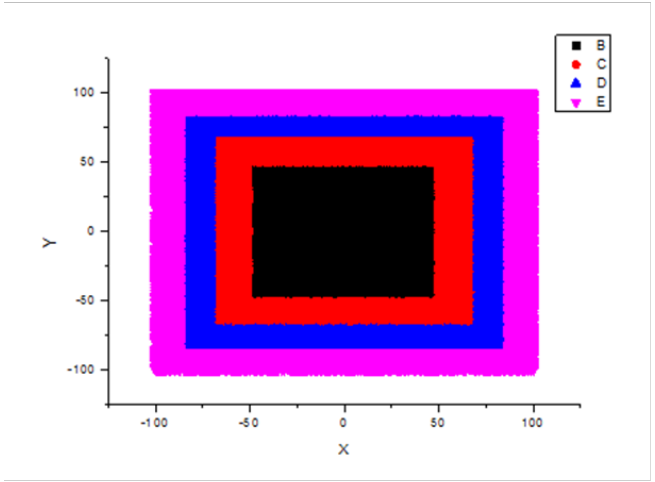
What's Machine Learning?



Machine Learning Algorithm

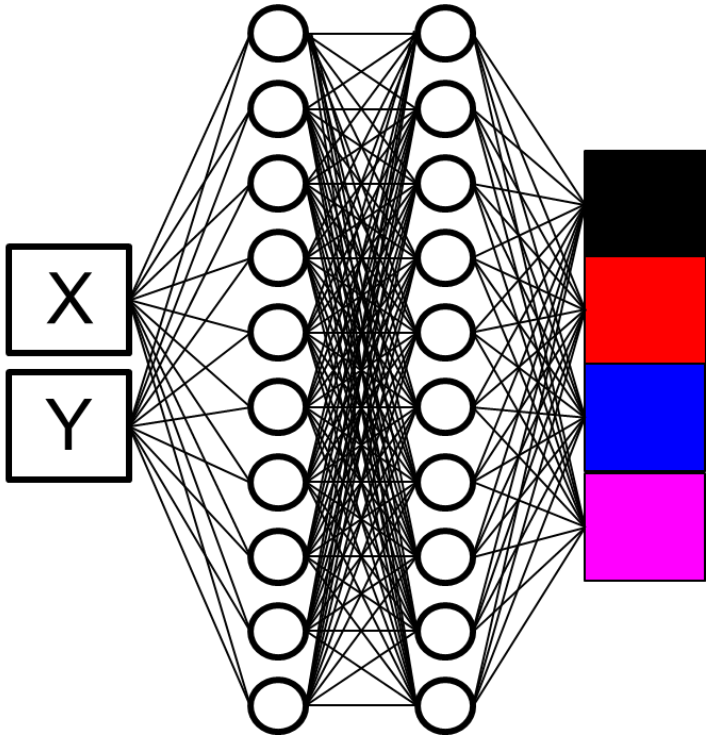
- Supported Vector Machine
- Recurrent neural network
- Convolutional neuron networks
- Convolutional deep belief networks
- ……

Simple Example of ANN



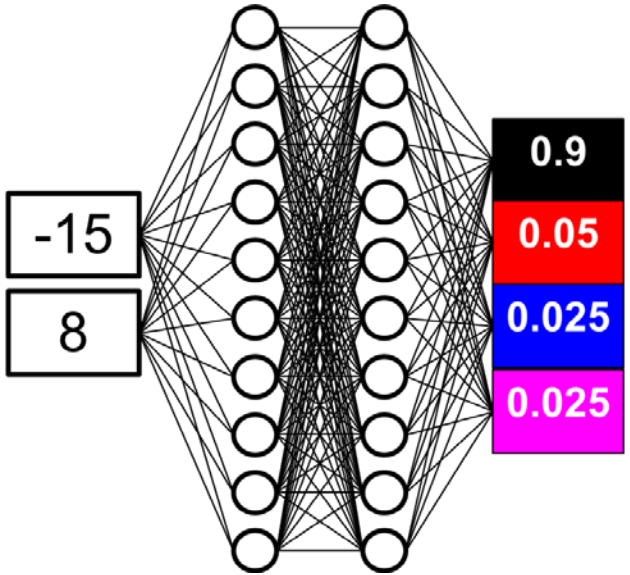
Training set:

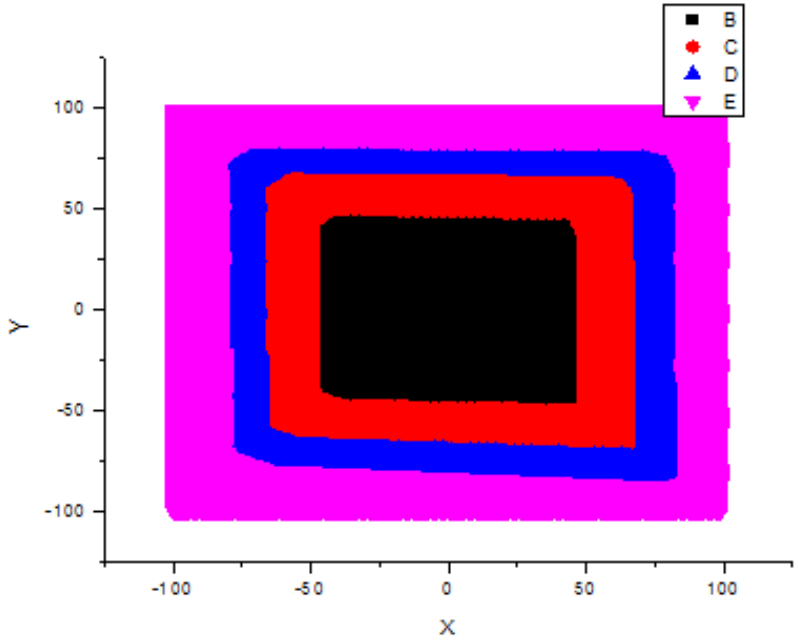
X	Y	Color
28	-10	Black
-50	-52	Red
-75	-73	Blue
-99	-98	Pink
52	0	Red
73	17	Blue
20	1	Black
3	100	Pink
80	7	Blue
-50	-45	Red
⋮	⋮	⋮



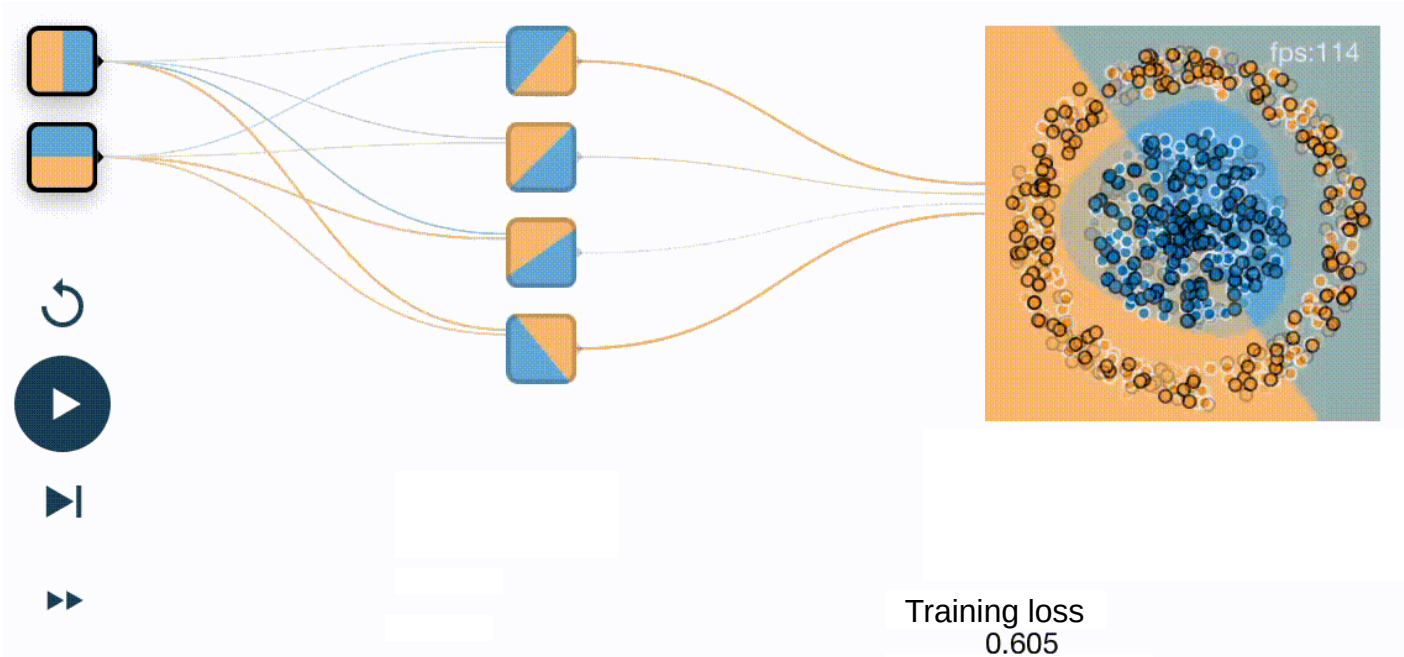
Simple Example of ANN

$$f(x, y) = \{\text{"Black","Red","Blue","Pink"}\}$$

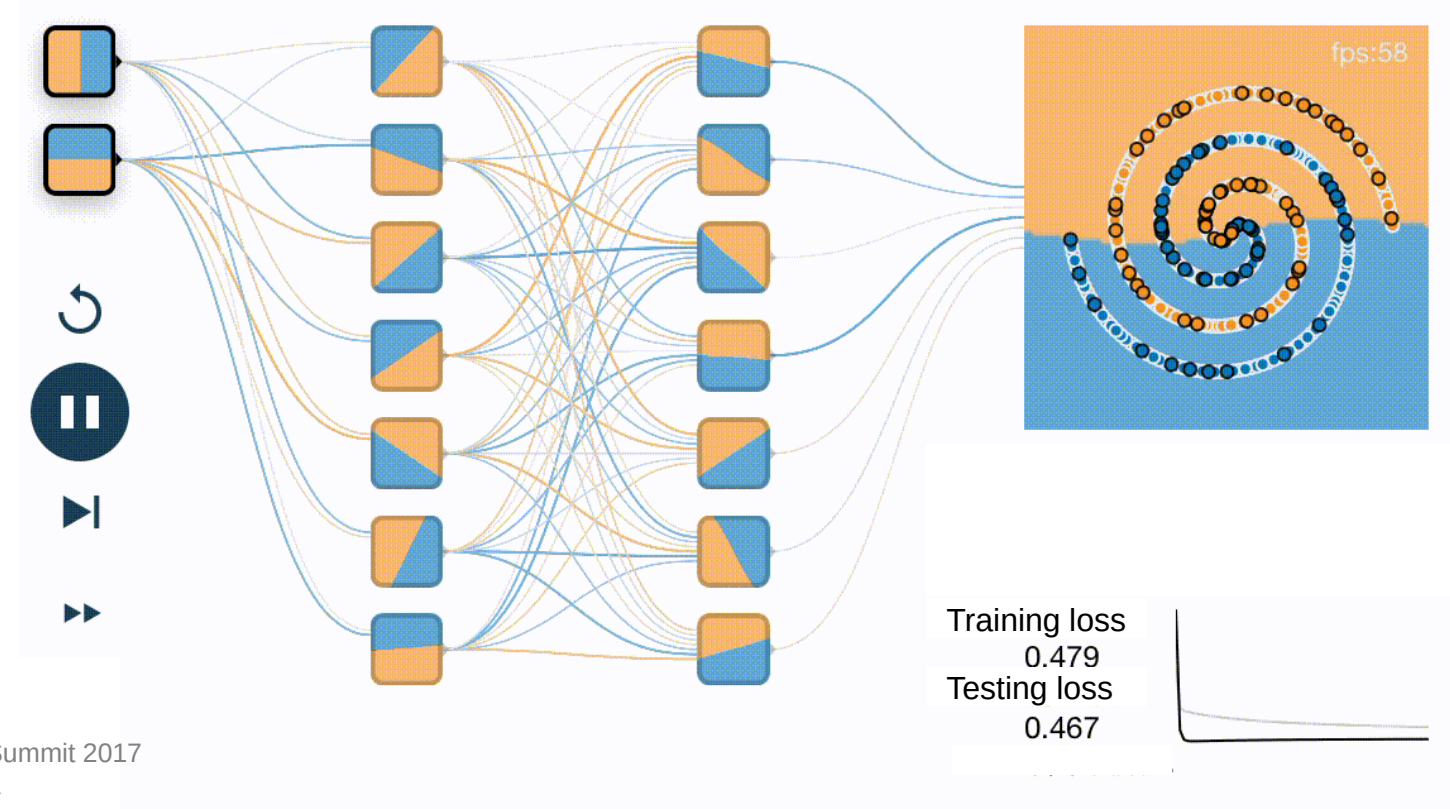




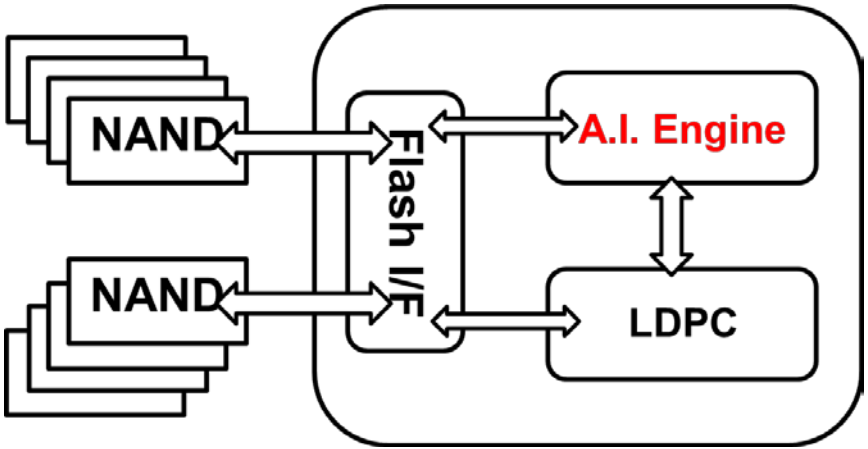
Artificial Neural Network(ANN)

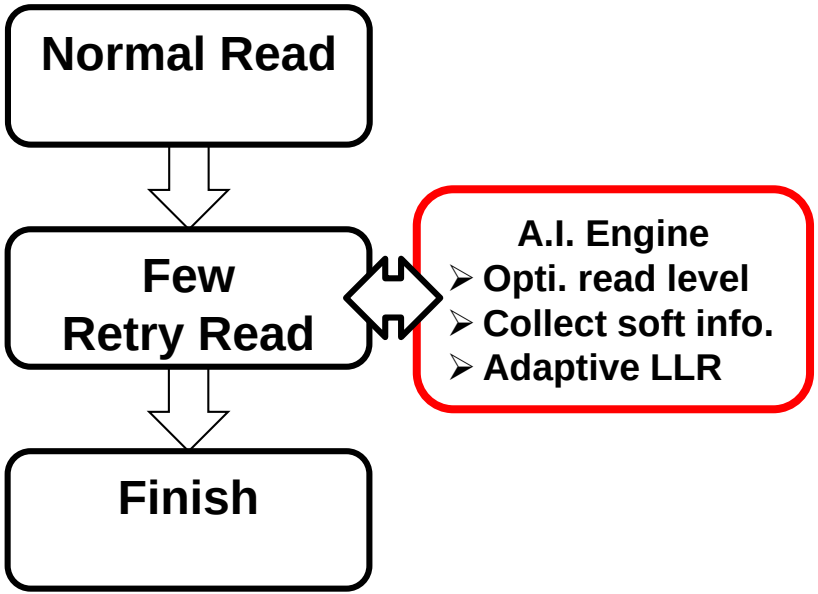


Artificial Neural Network(ANN)



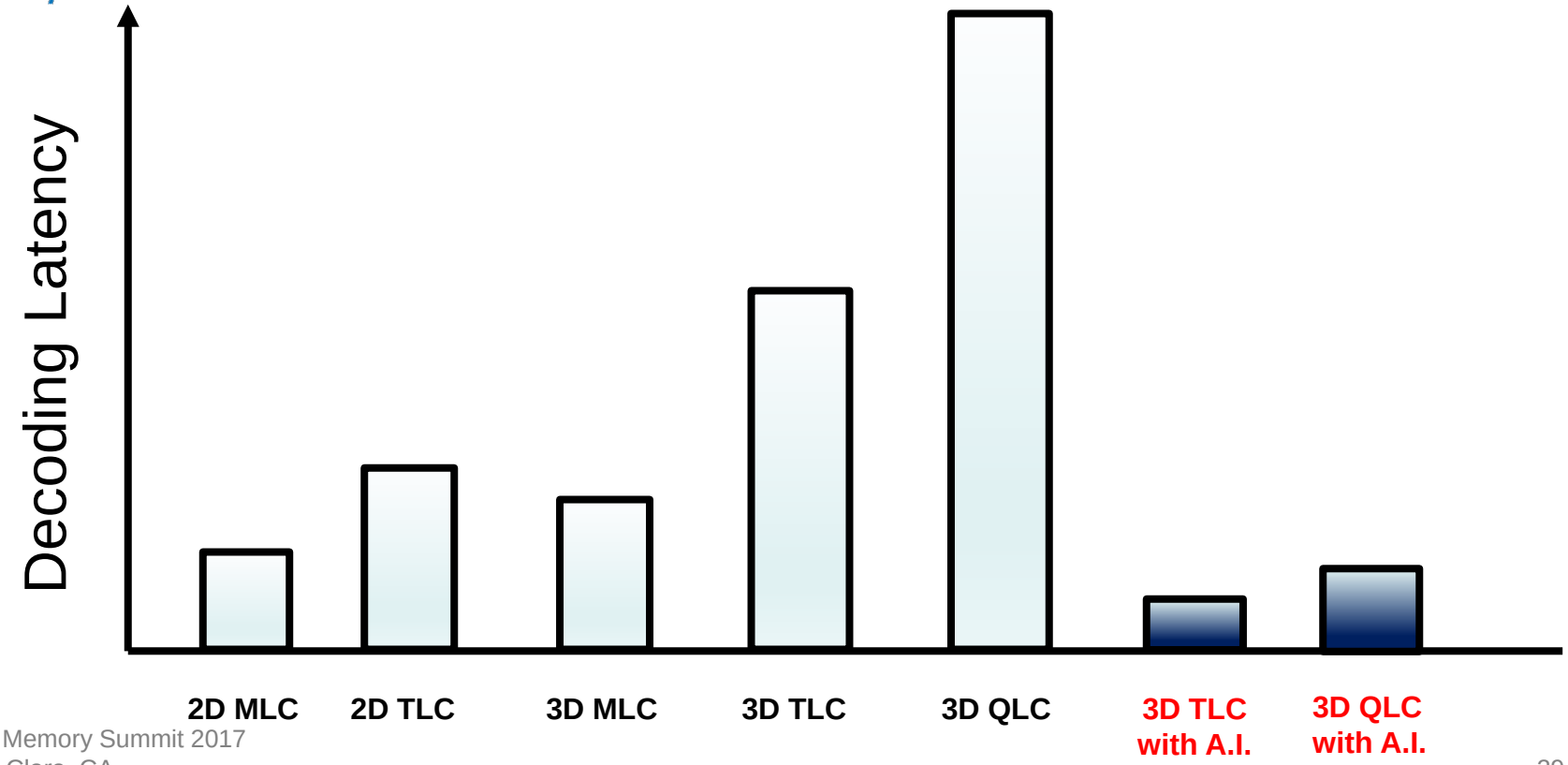
DSP Based on Machine Learning



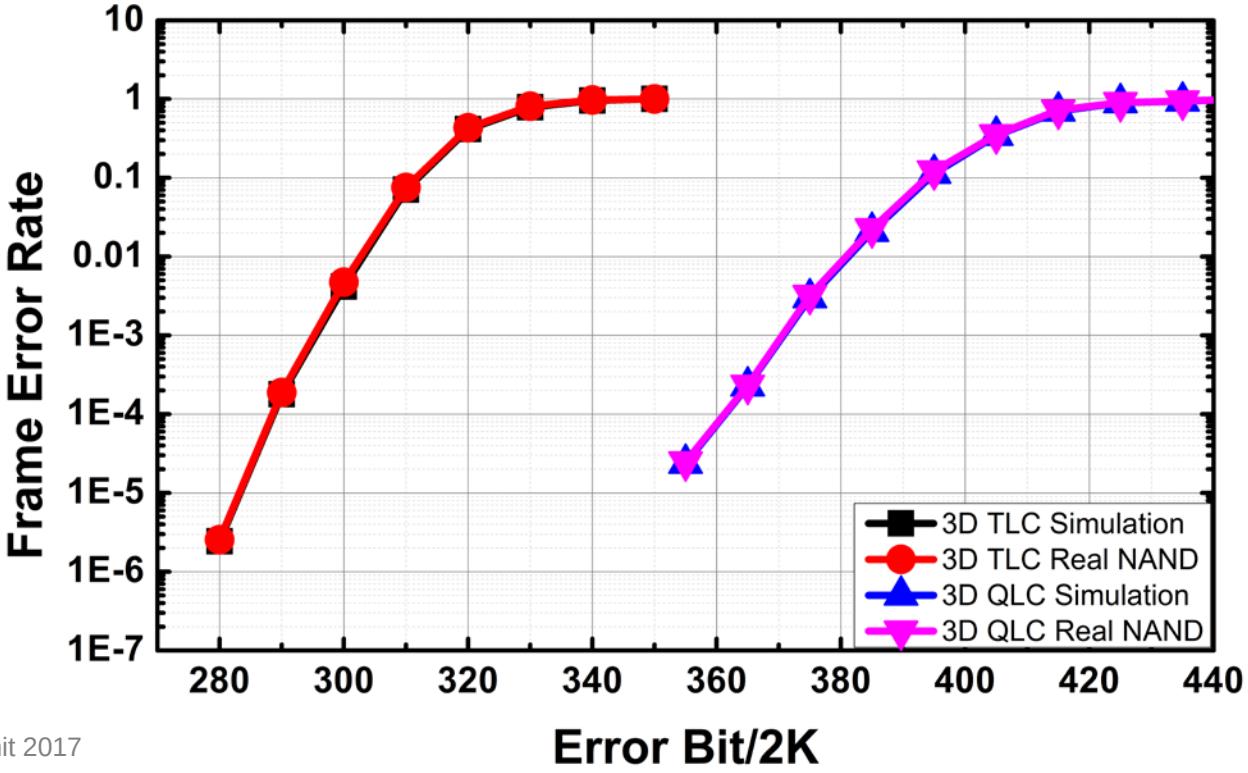


- DSP engine makes the decoding flow of LDPC as simple as BCH

Decoding Latency with A.I. engine



Correction Capability with A.I. DSP



Thanks for your attention