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Computation Reuse in DNNs by Exploiting Input Similarity

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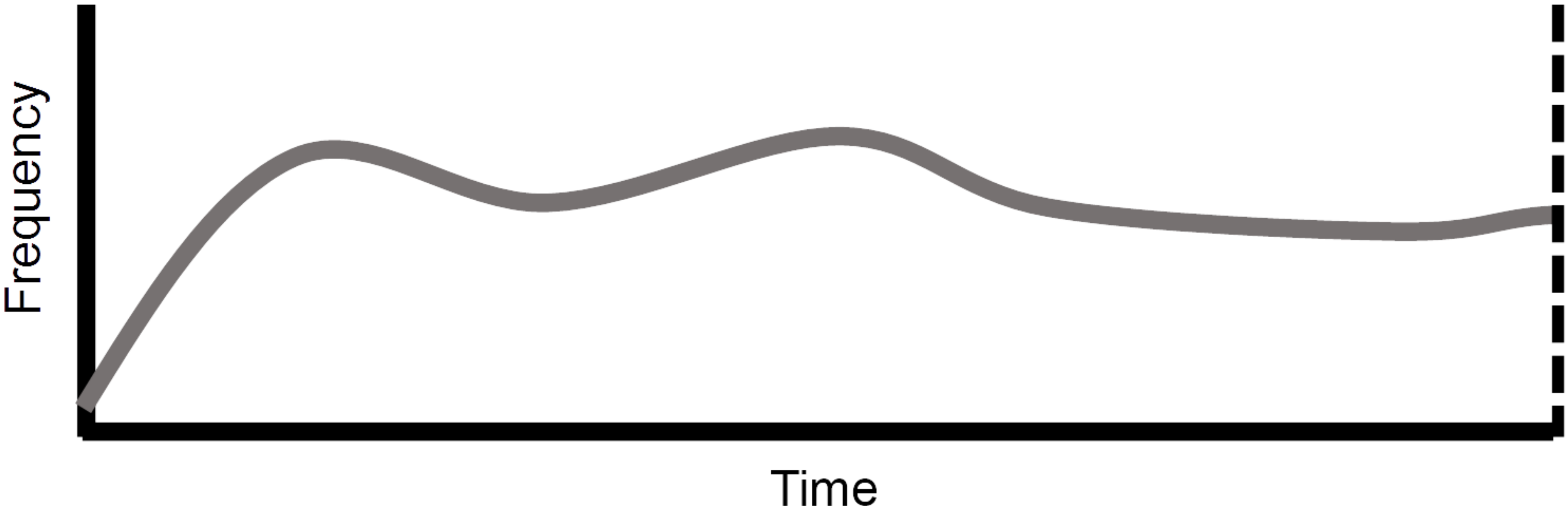
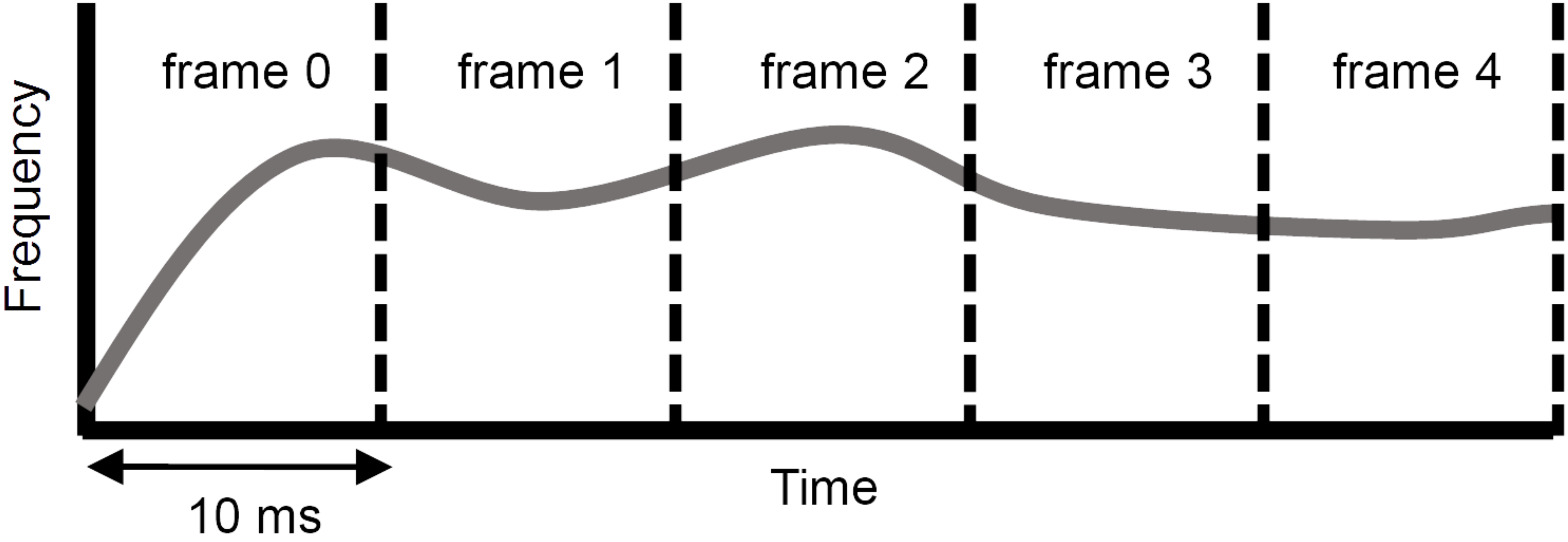
Sequence Processing Applications

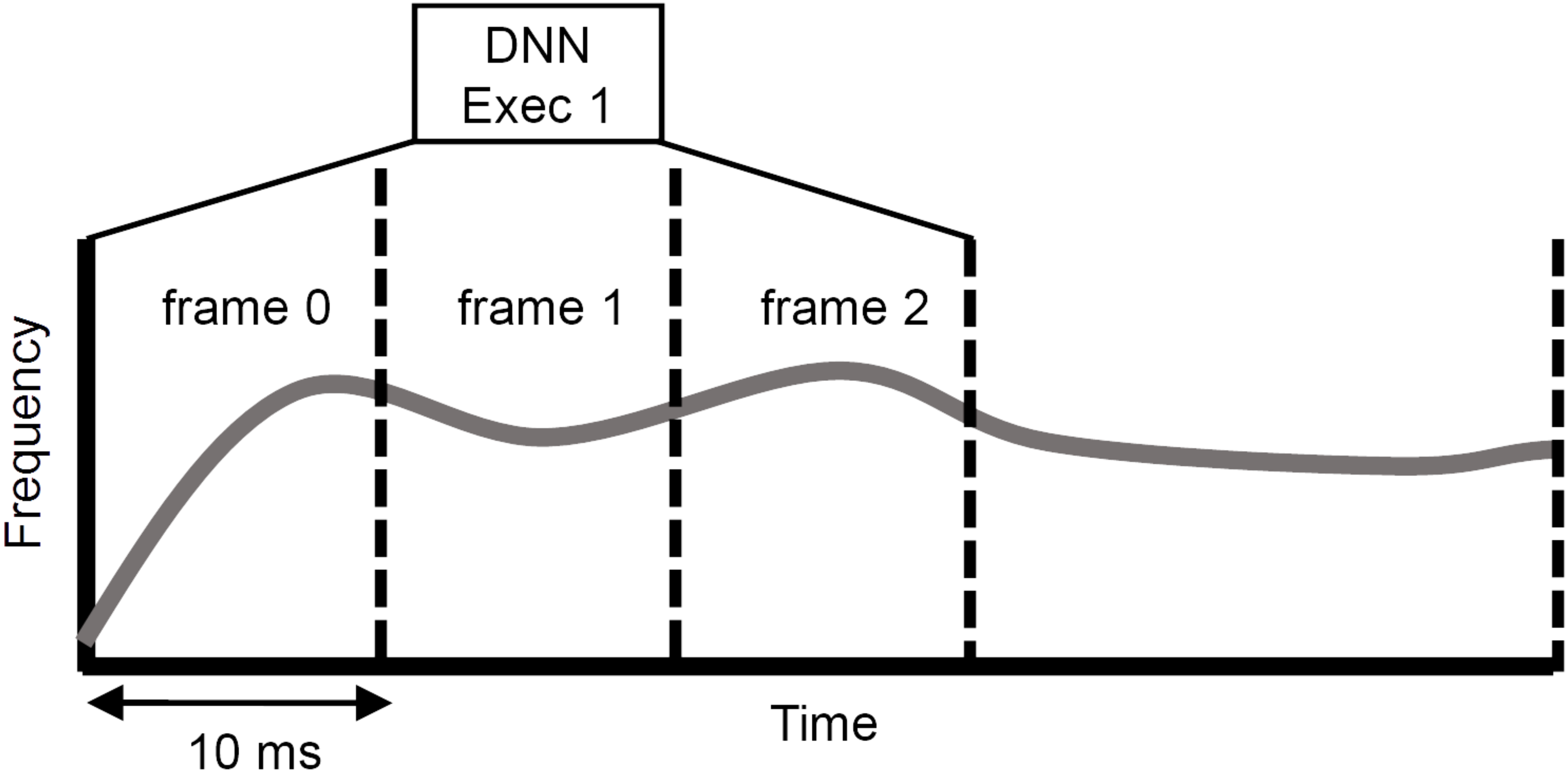
Speech Audio Signal



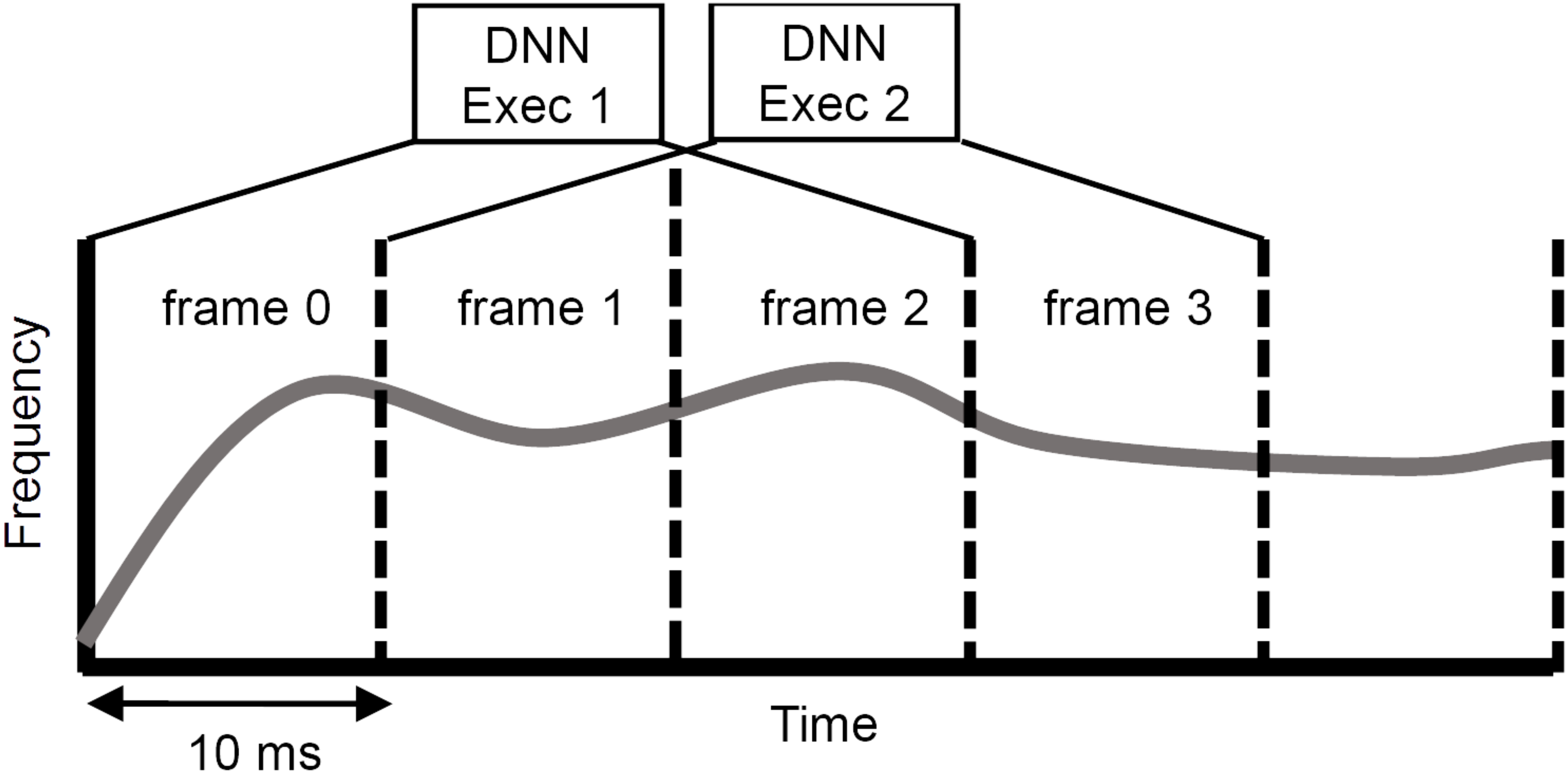
Sequence Processing Applications



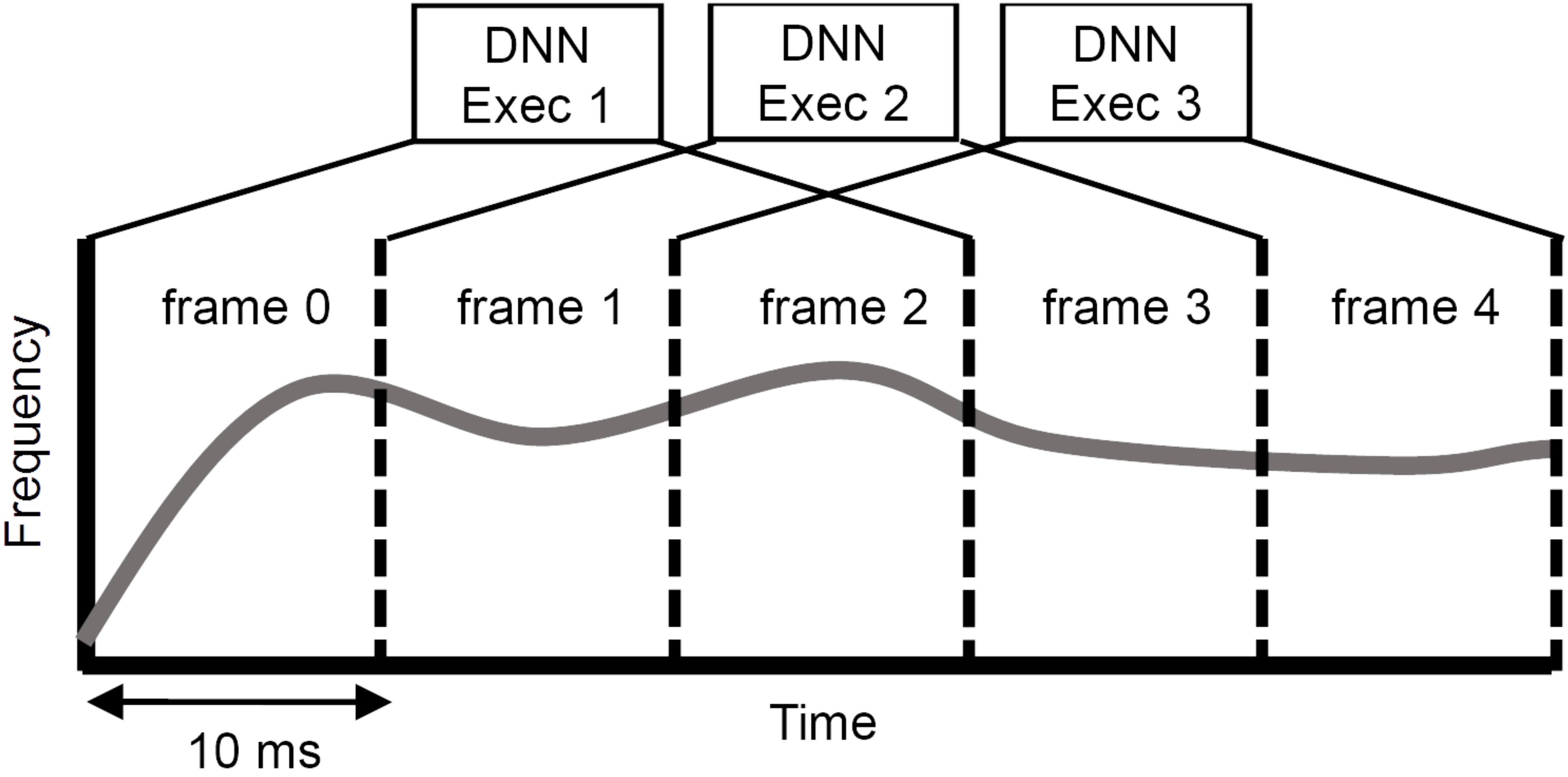
Sequence Processing Applications



Sequence Processing Applications



Sequence Processing Applications

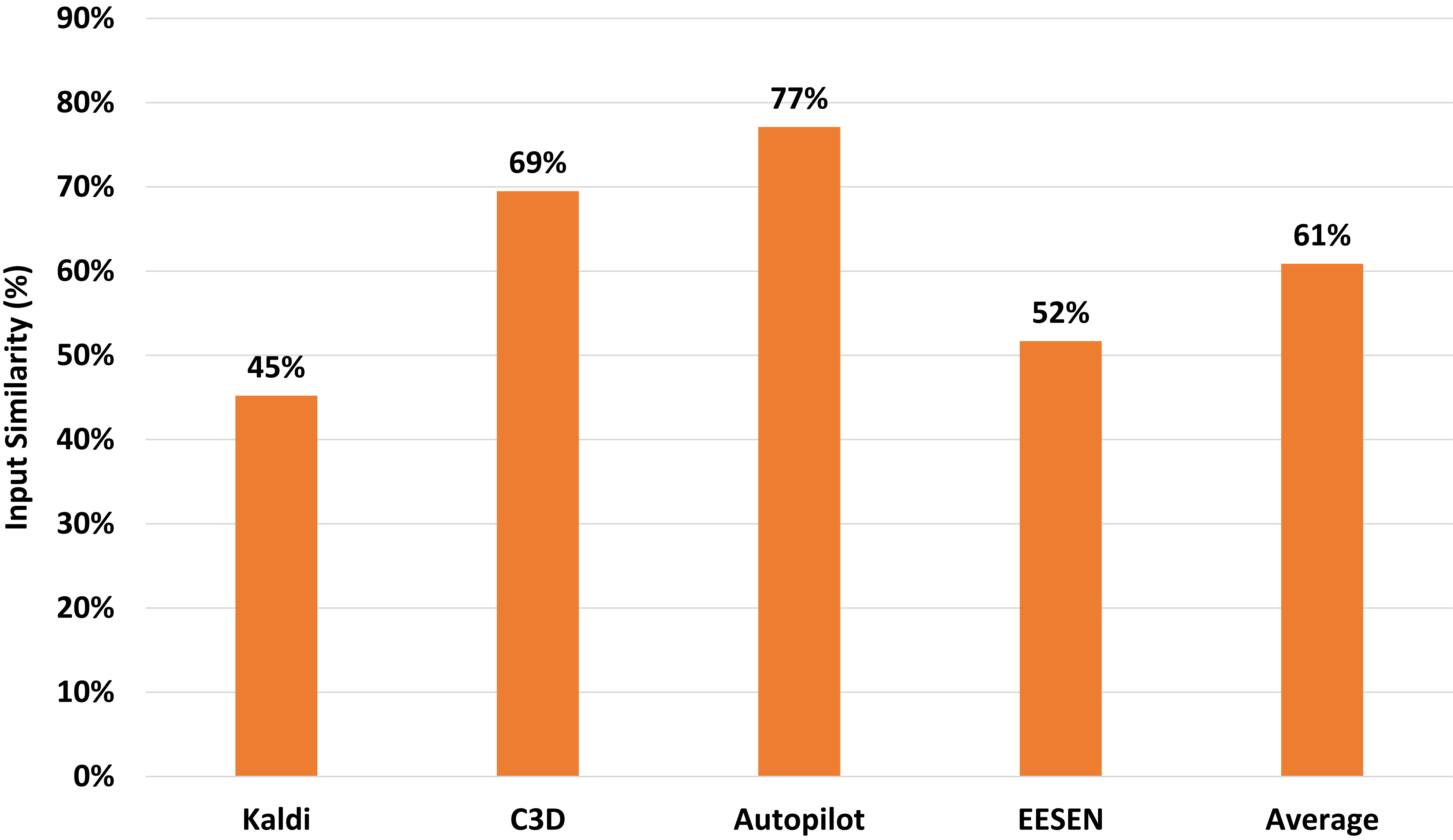


Speech Recognition DNN executions to classify a sequence of audio frames in phonemes

Benchmarks

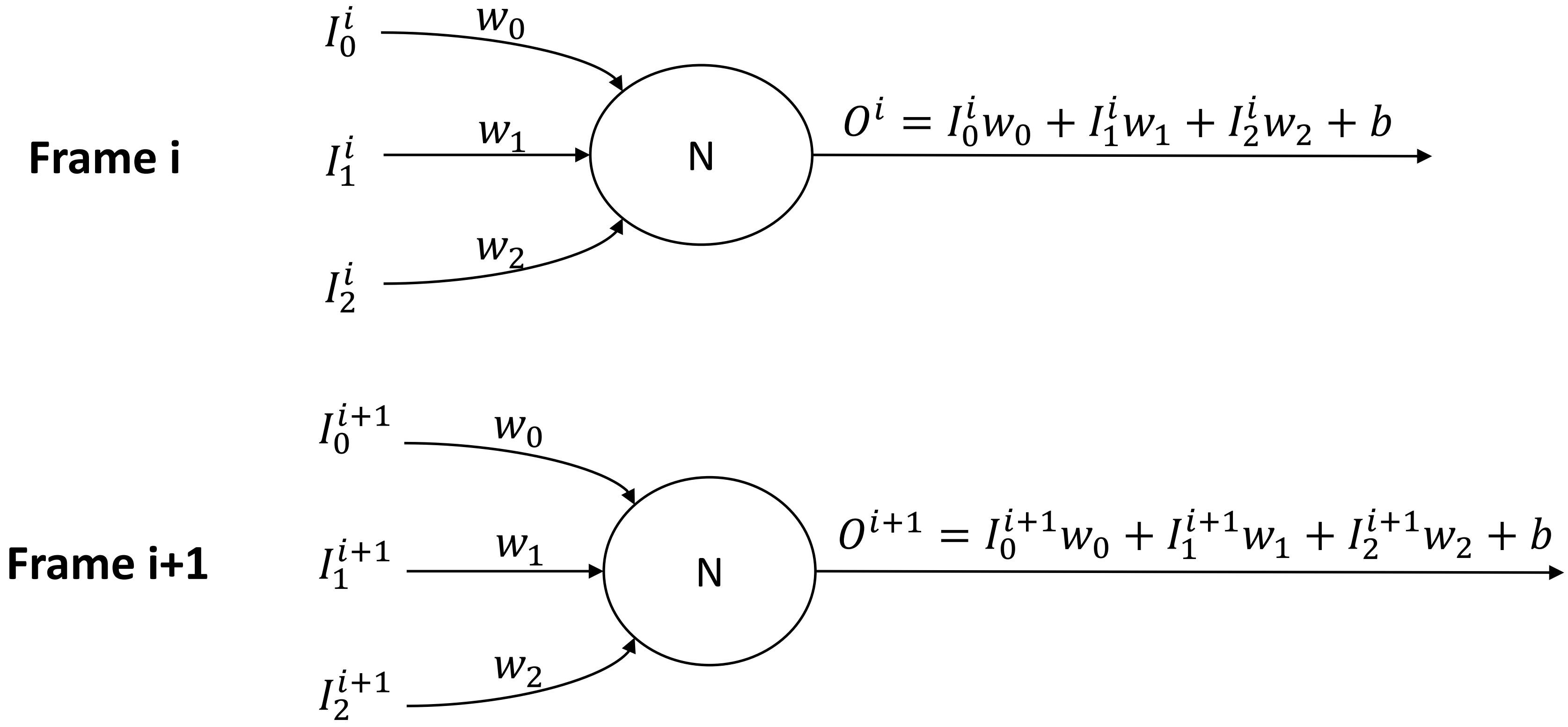
DNN Name	DNN Type	DNN Application	#Parameters	Accuracy
Kaldi	MLP	Acoustic Scoring	4,7M	89,04%
EESEN	RNN	Speech Recognition	11M	68,85%
C3D	CNN	Video Classification	78M	93,48%
AutoPilot	CNN	Self-Driving Cars	1,6M	99,63%

Input Similarity



Exploiting Temporal Similarity Example

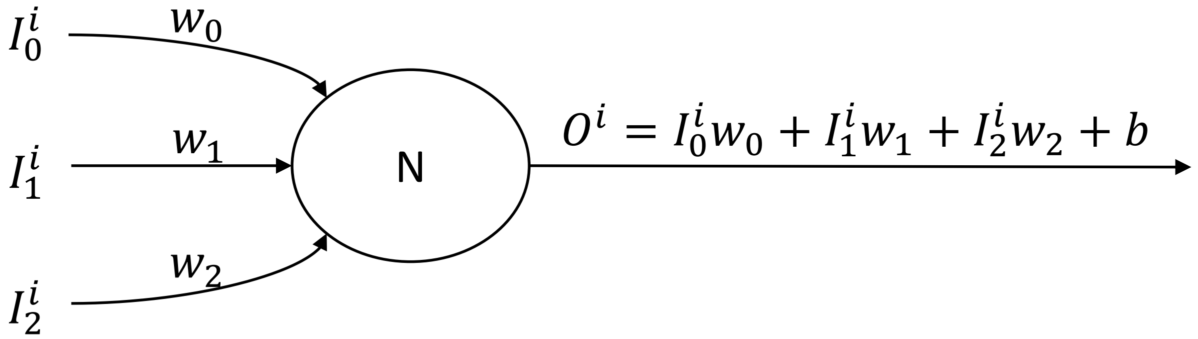
Baseline


Frame i
I_0^i
w_0
I_1^i
w_1
I_2^i
w_2
N
$O^i = I_0^i w_0 + I_1^i w_1 + I_2^i w_2 + b$
Frame i+1
I_0^{i+1}
w_0
I_1^{i+1}
w_1
I_2^{i+1}
w_2
N
$O^{i+1} = I_0^{i+1} w_0 + I_1^{i+1} w_1 + I_2^{i+1} w_2 + b$

Exploiting Temporal Similarity Example

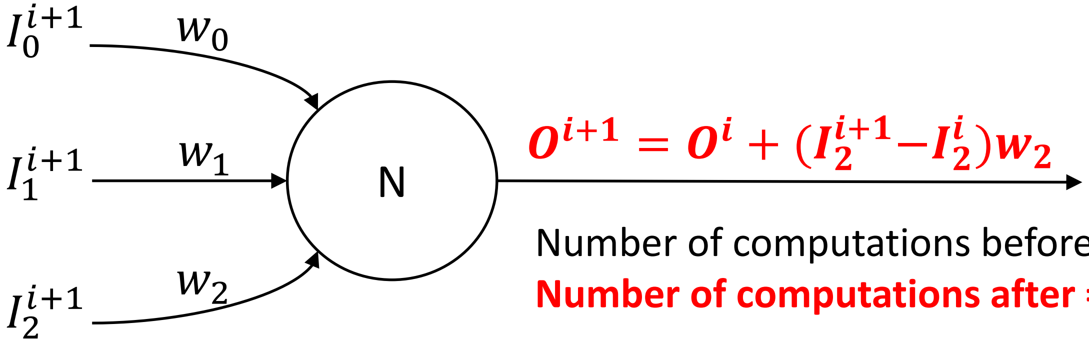
Proposal

Frame i



$$O^i = I_0^i w_0 + I_1^i w_1 + I_2^i w_2 + b$$

Frame i+1



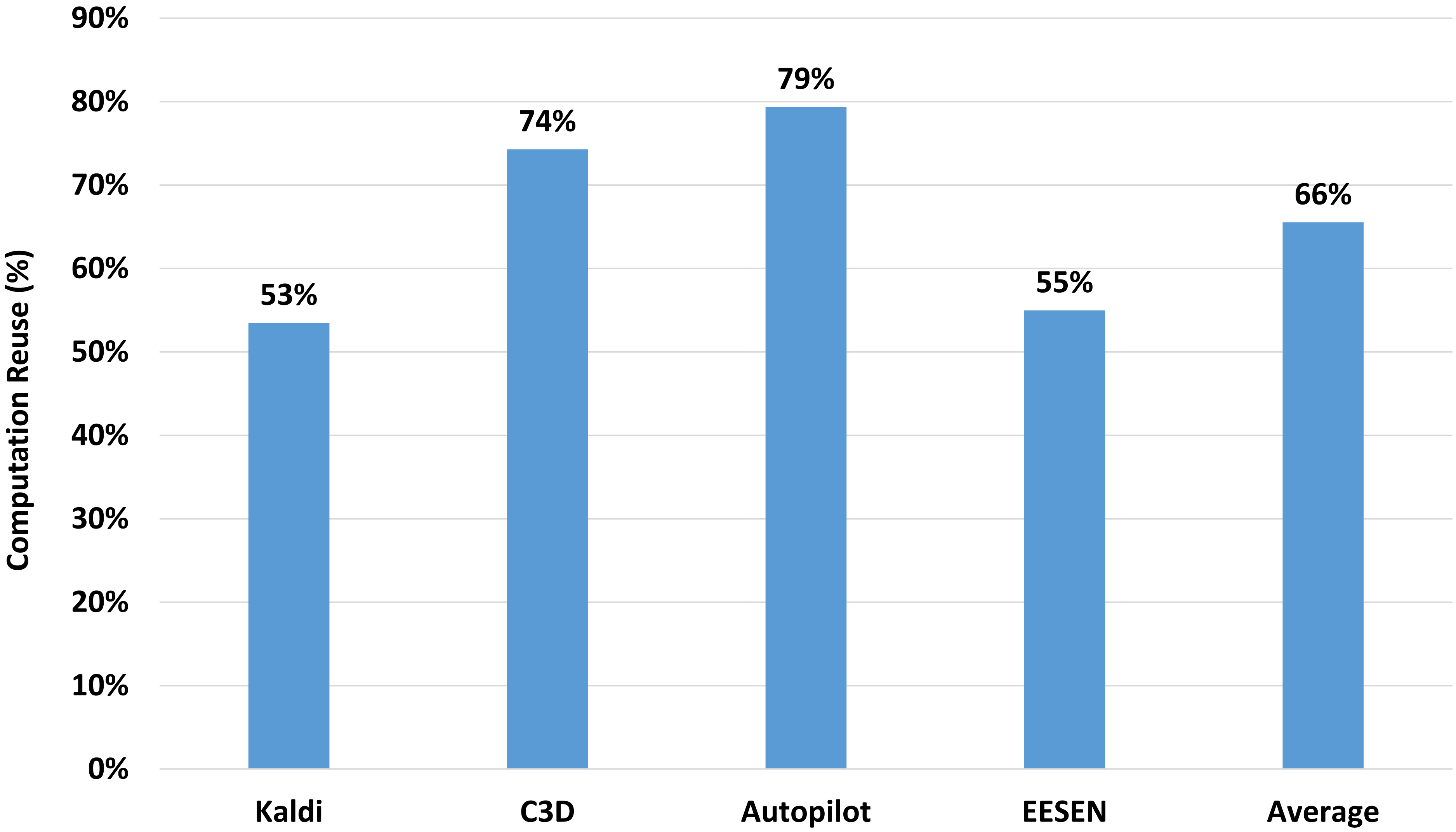
$$\boldsymbol{O^{i+1} = O^i + (I_2^{i+1} - I_2^i) w_2}$$

Number of computations before = 6

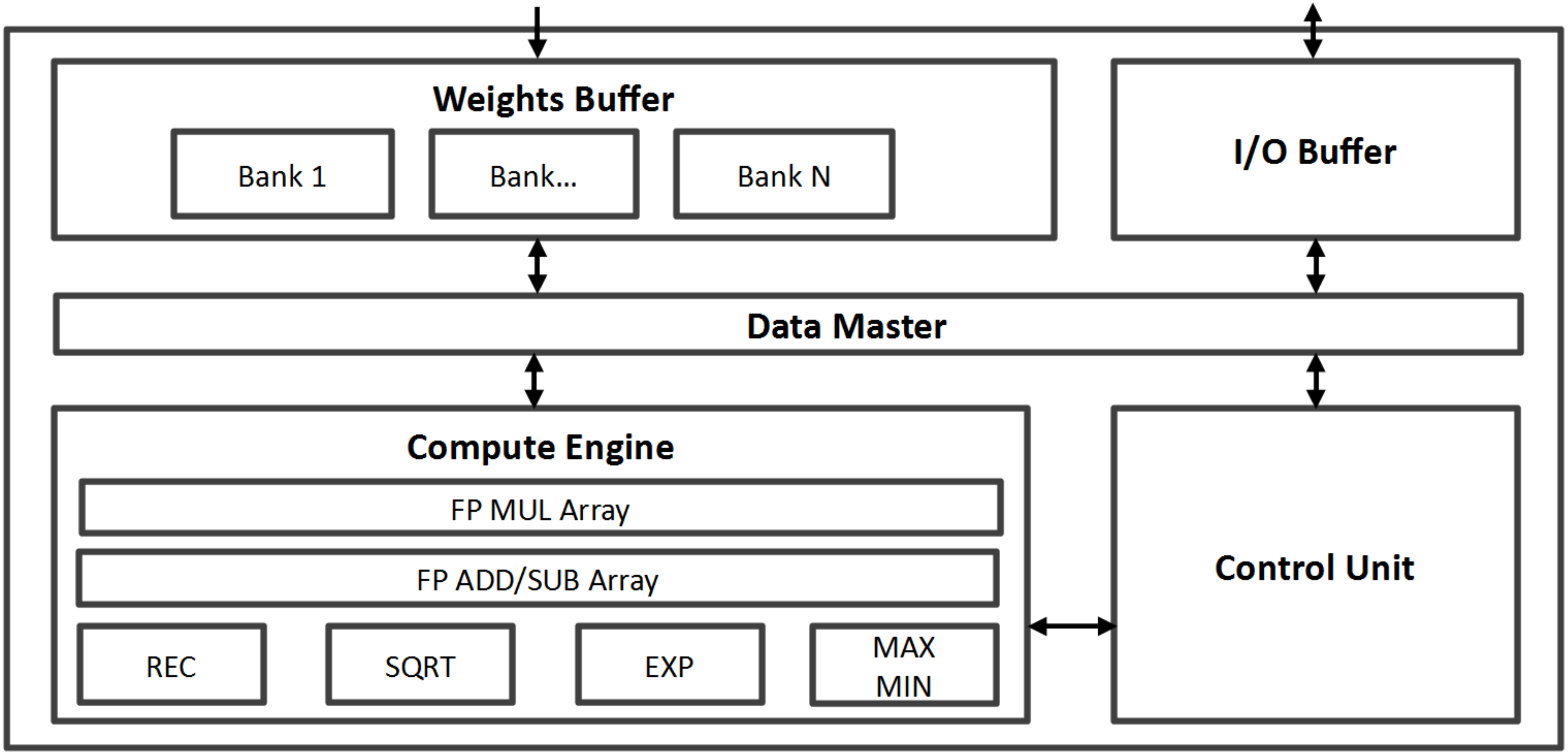
Number of computations after = 2

Note: Substraction of the inputs is almost negligible since its performed once per input

Computation Reuse

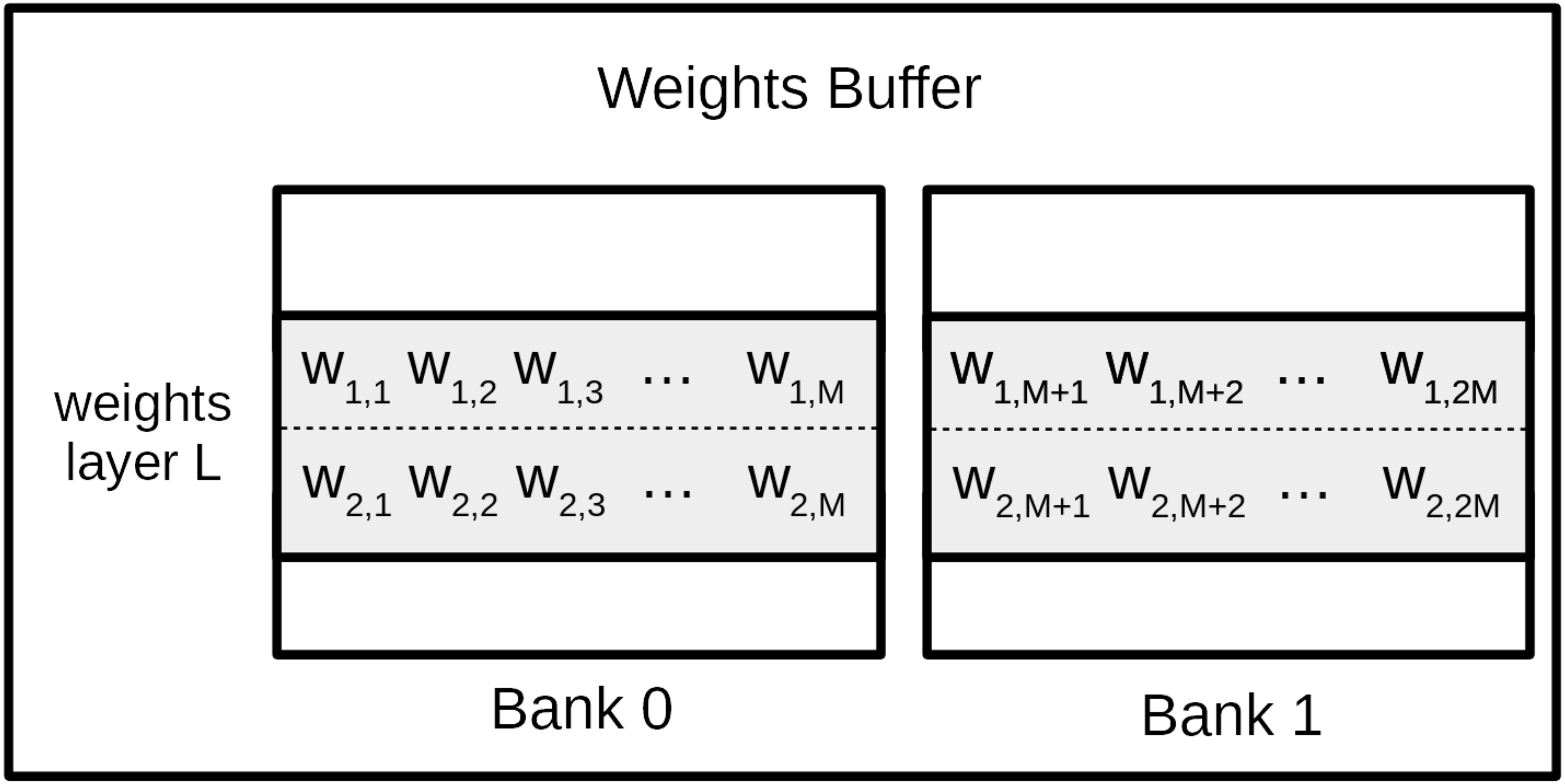


DNN Processing Unit



Tile

FC Execution in the Reuse Accelerator (1)



Weights Buffer

weights layer L

$W_{1,1}$ $W_{1,2}$ $W_{1,3}$ … $W_{1,M}$

$W_{2,1}$ $W_{2,2}$ $W_{2,3}$ … $W_{2,M}$

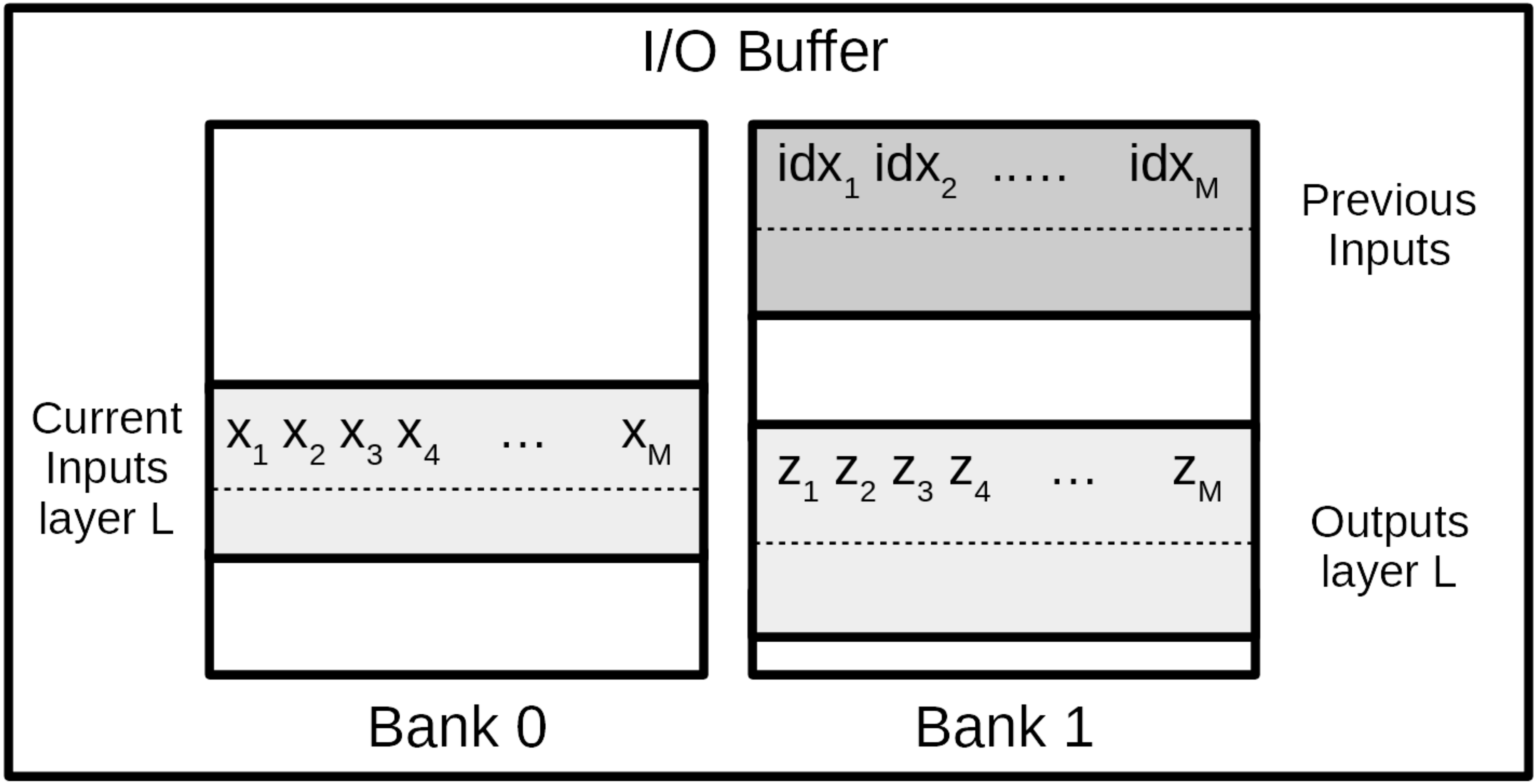
Bank 0

$W_{1,M+1}$ $W_{1,M+2}$ … $W_{1,2M}$

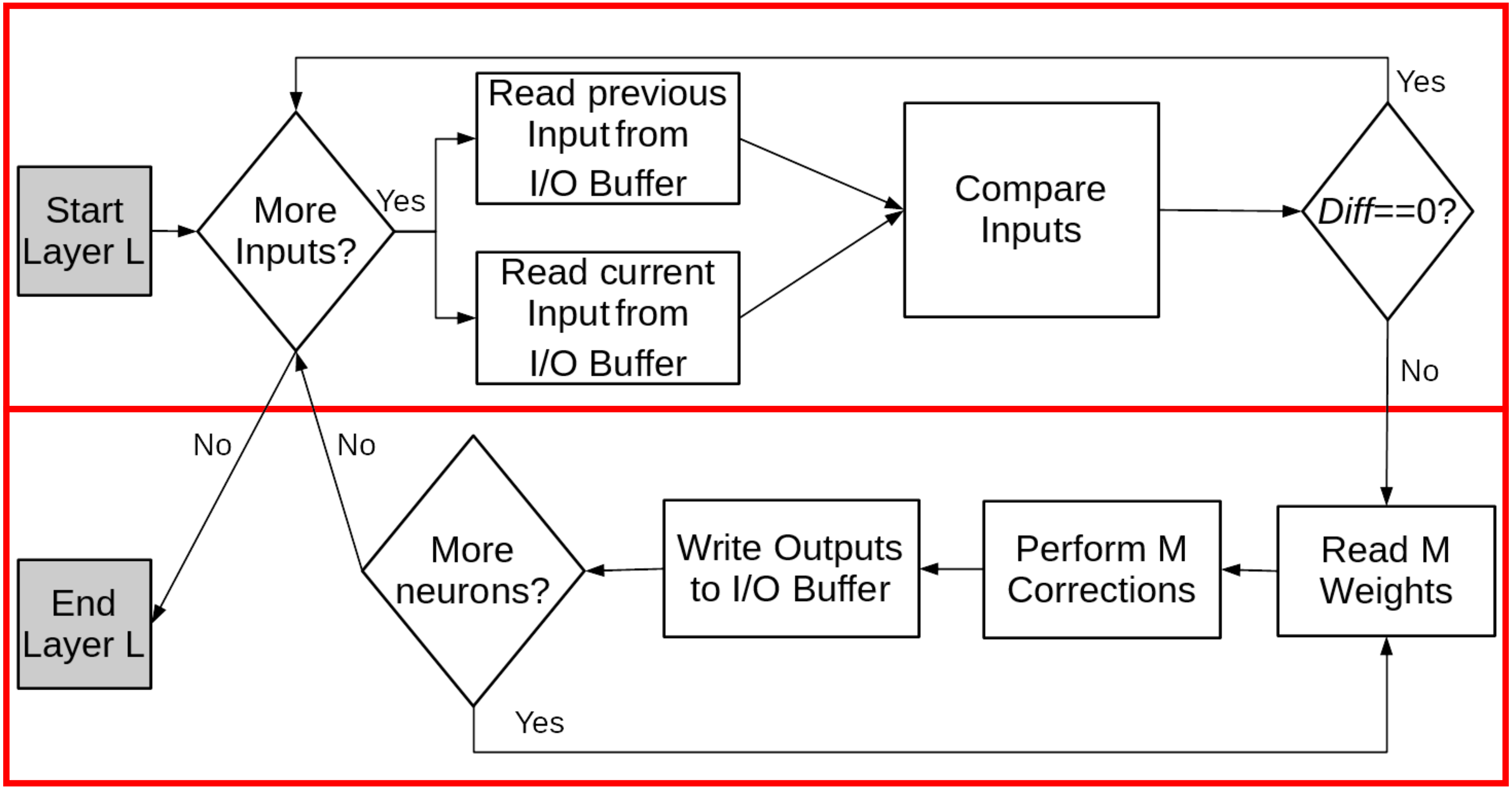
$W_{2,M+1}$ $W_{2,M+2}$ … $W_{2,2M}$

Bank 1

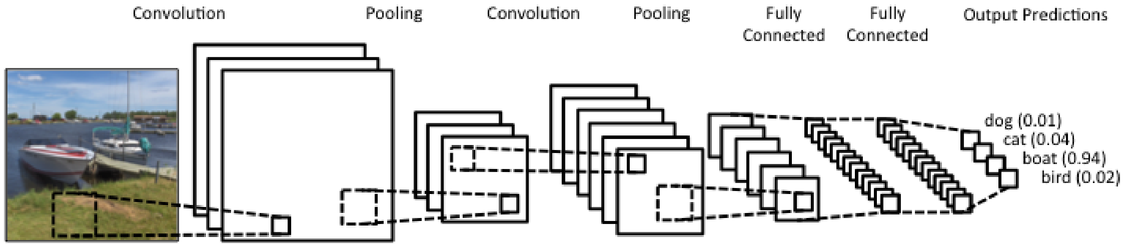
FC Execution in the Reuse Accelerator (2)


I/O Buffer
idx$_1$ idx$_2$ ..... idx$_M$
Previous Inputs
Current Inputs layer L
x$_1$ x$_2$ x$_3$ x$_4$ … x$_M$
z$_1$ z$_2$ z$_3$ z$_4$ … z$_M$
Outputs layer L
Bank 0
Bank 1

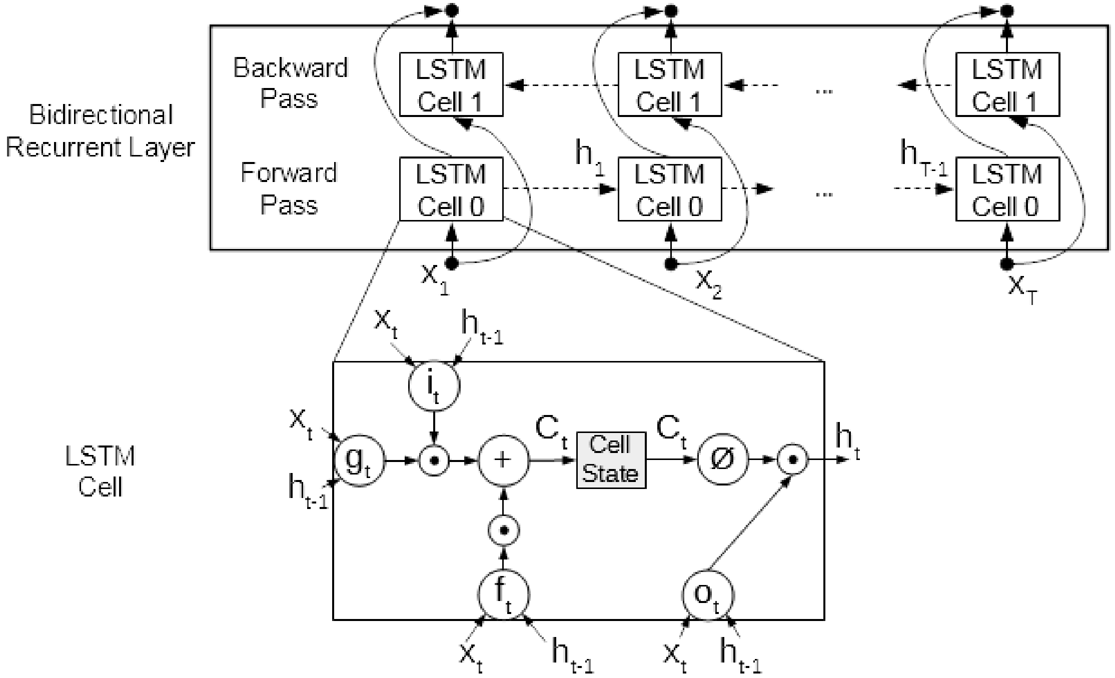
FC Execution in the Reuse Accelerator (3)



Other Supported Layers



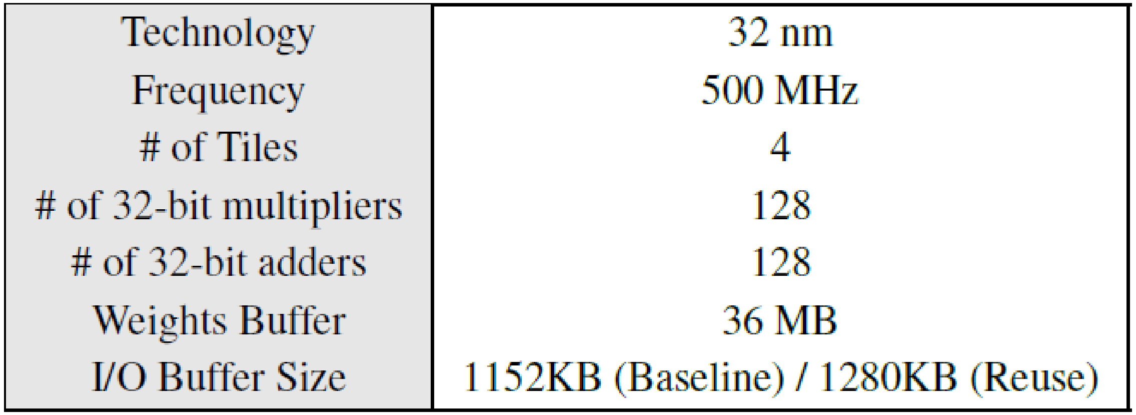
Convolutional Neural Network (CNN)



Recurrent Neural Network (RNN)

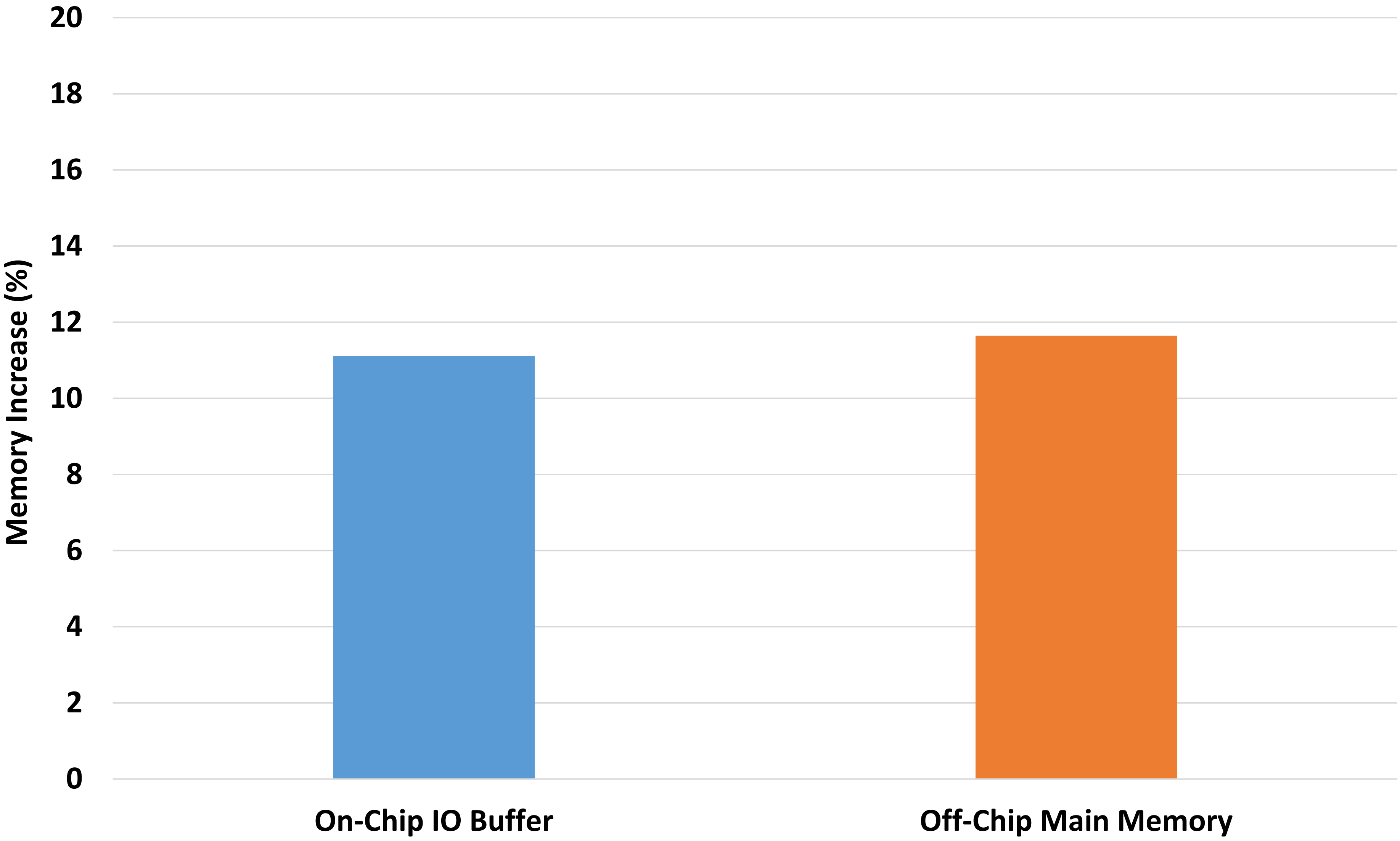
Evaluation Methodology

- Simulator to evaluate the performance and energy of the accelerator
- Design Compiler to obtain power and delay of logic modules
  - 28/32nm library from Synopsys and the DesignWare logic modules
- CACTI used for SRAM and eDRAM memories
- MICRON LPDDR4 for main Memory
- Accelerator Configuration:

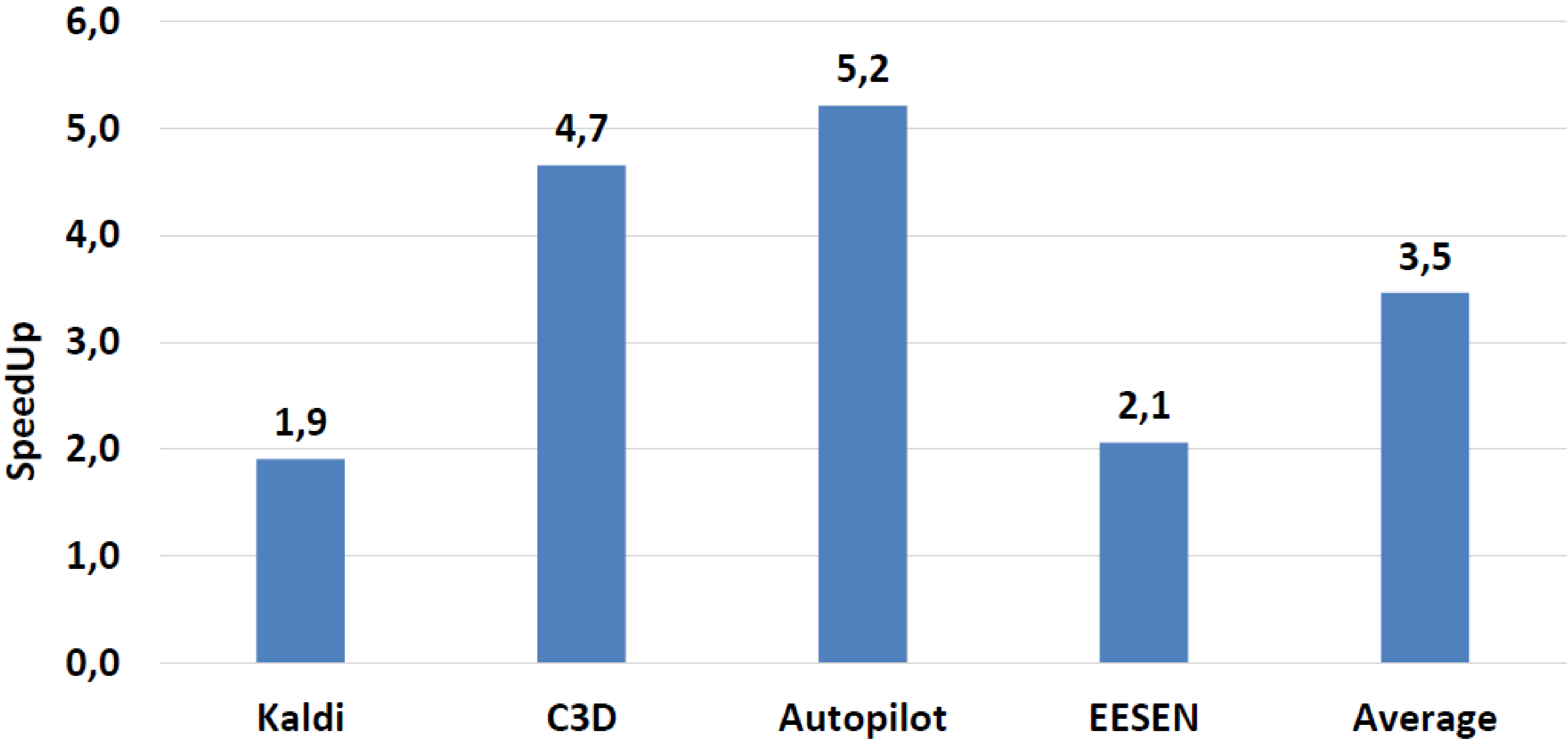


Technology	32 nm
Frequency	500 MHz
# of Tiles	4
# of 32-bit multipliers	128
# of 32-bit adders	128
Weights Buffer	36 MB
I/O Buffer Size	1152KB (Baseline) / 1280KB (Reuse)

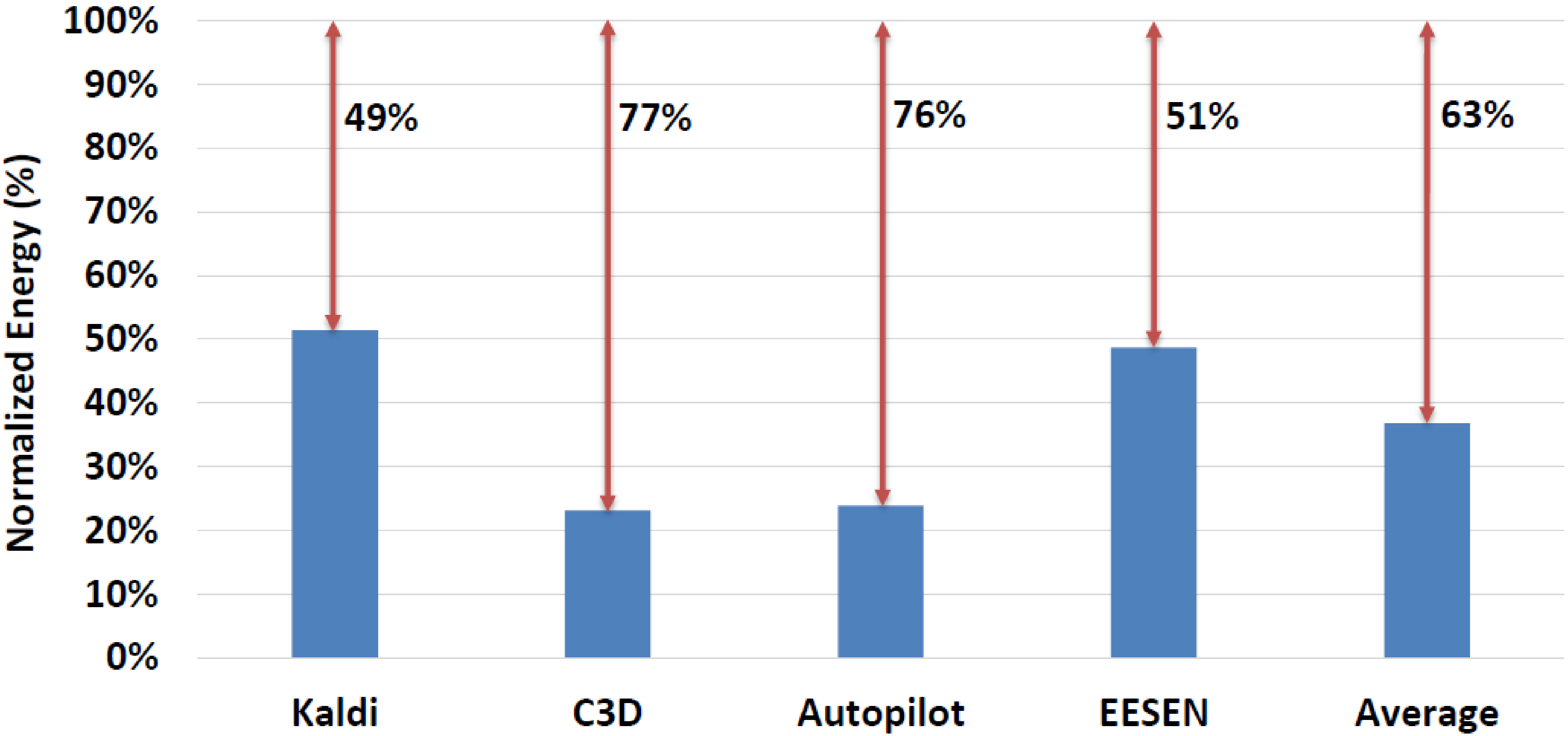
Memory Footprint Overheads



Results: SpeedUp



Results: Energy Savings



Conclusions

- More than 60% of the inputs remain unmodified respect the previous execution
- Our proposed scheme checks which inputs have changed:
  - Unmodified inputs are ignored, avoiding computations and memory accesses
  - Modified inputs are used to correct the previous output of each neuron
- On average, 63% energy savings and 3.5x speedup
- Small area overhead of less than 1% mainly for additional storage

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