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# FPGA implementation of Oscillatory Neural Networks for Artificial Intelligence edge computing

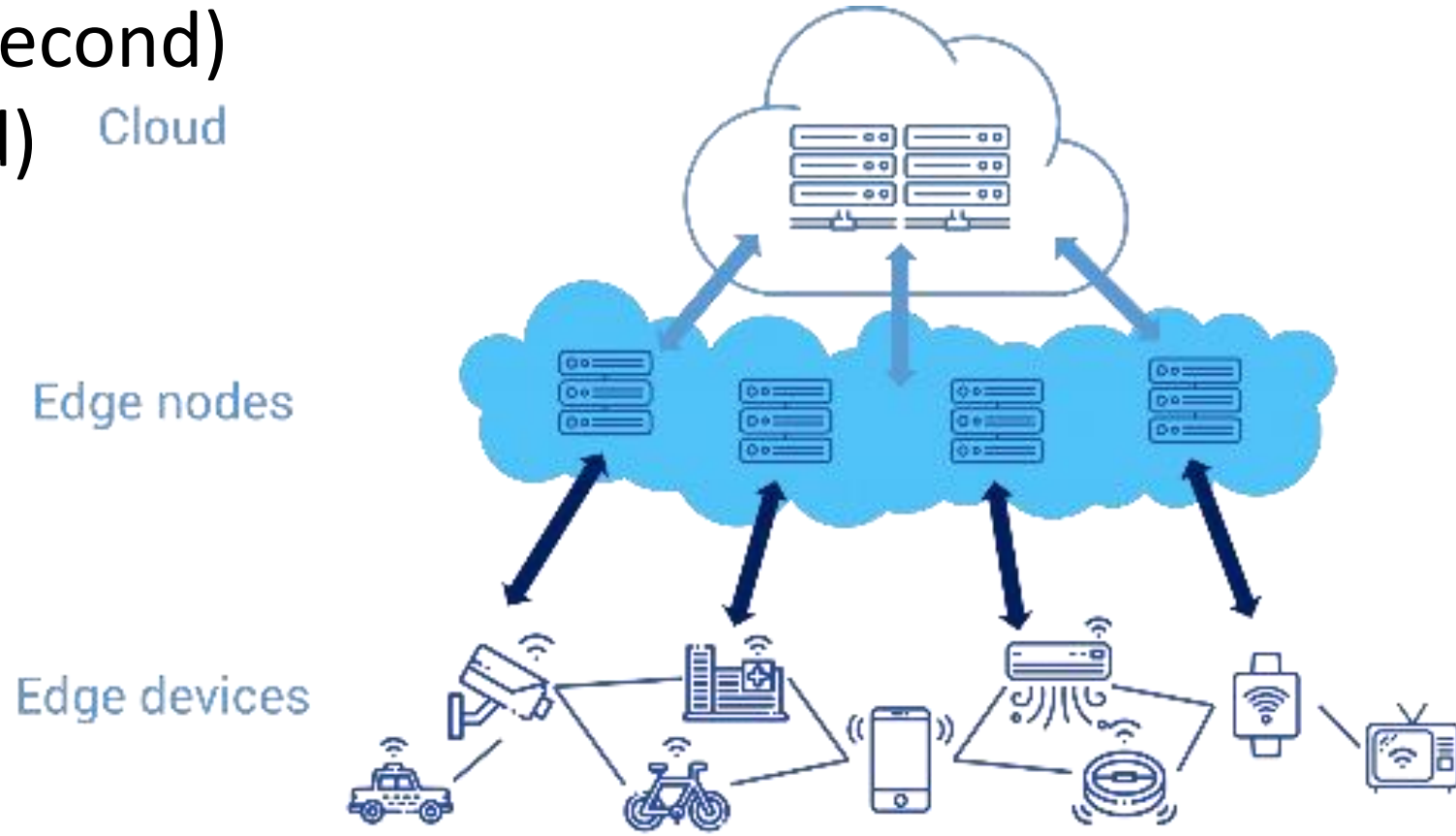


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## MOTIVATION AND GOALS

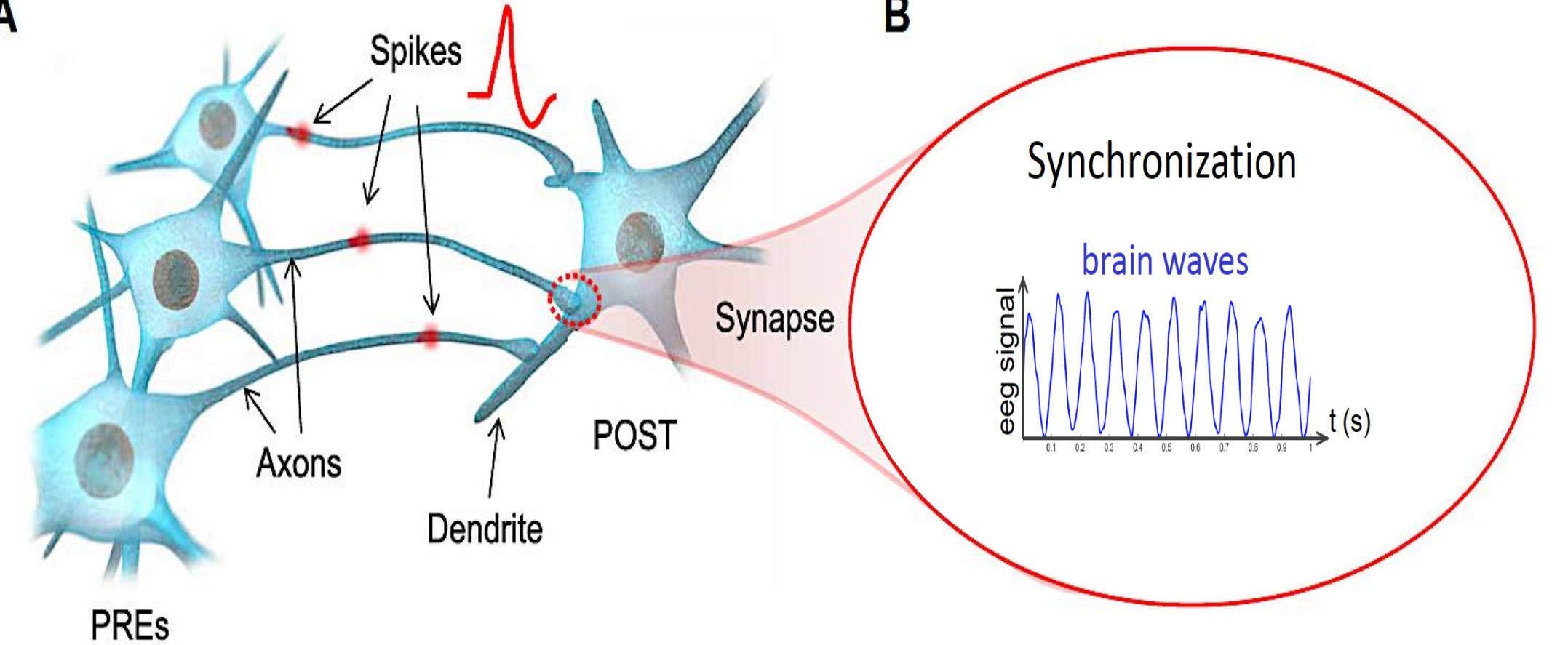
### ARTIFICIAL INTELLIGENCE AT THE EDGE

- Bandwidth (inference/second)
- Latency (frames/second)
- Privacy concerns
- Power consumption



### NEUROMORPHIC COMPUTING

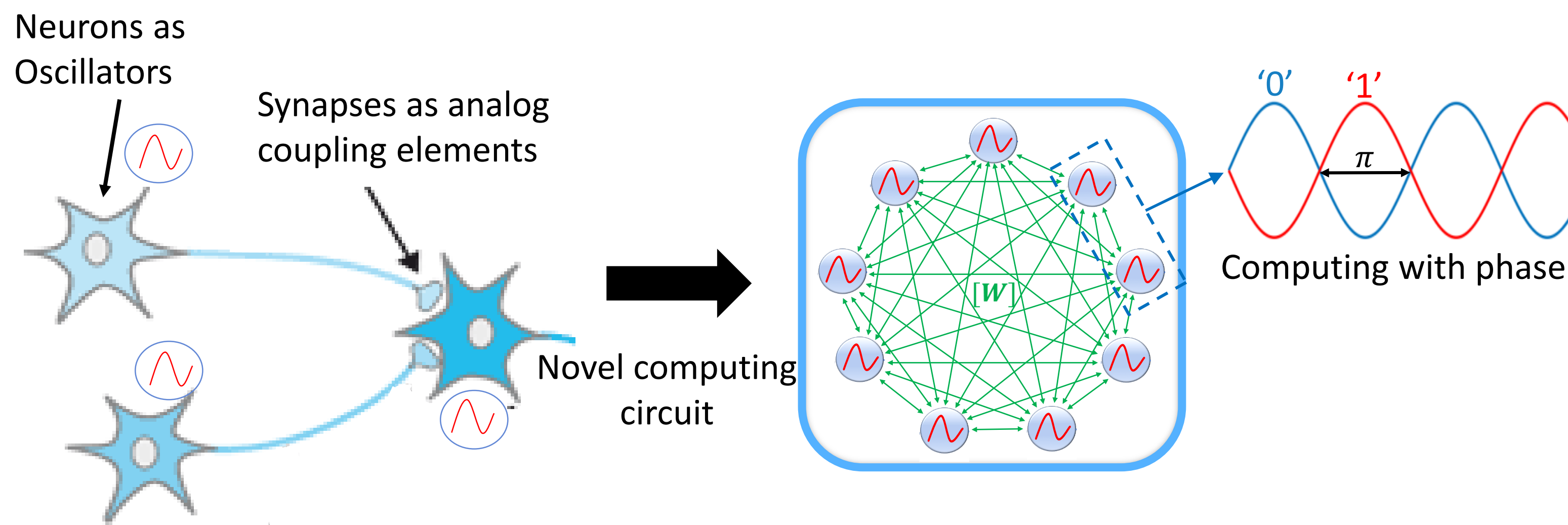
- Support online learning
- Excellent inference engine
- Low power consumption
- Scalable/low cost



## OSCILLATORY NEURAL NETWORKS

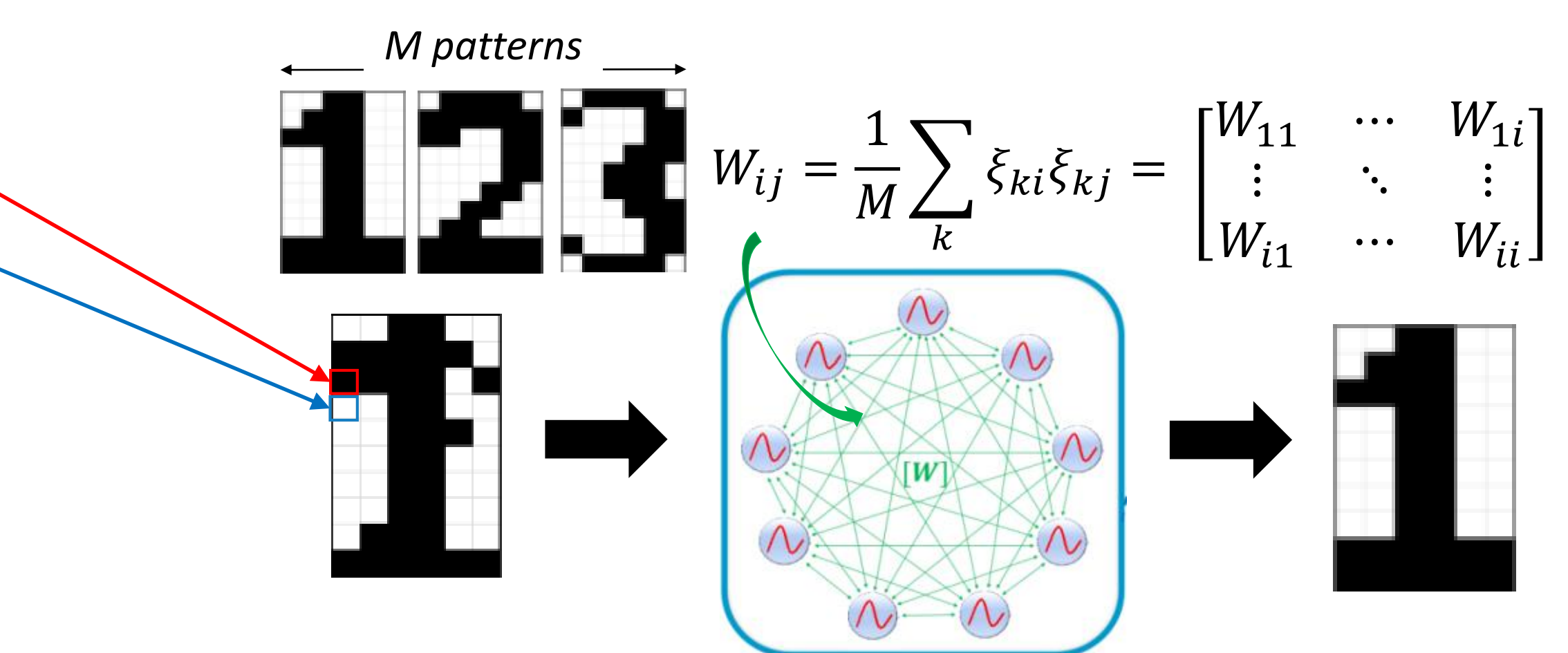
### BRAIN INSPIRED COMPUTING PARADIGM

- Oscillatory Neural Networks with phase computation for energy-efficient analog circuit design [1]



### ASSOCIATIVE MEMORY LEARNING AND INFERENCE

- Learning to define weights with patterns using unsupervised Hebbian Learning rule [2].
- Inference to retrieve a learnt pattern from a noisy one.



## FPGA IMPLEMENTATION FOR DEMONSTRATORS AND USE CASES

### DIGITAL ONN IMPLEMENTATION ON FPGA [3]

- Digital ONN prototype on FPGA-based Zybo-Z7 board for demonstrations

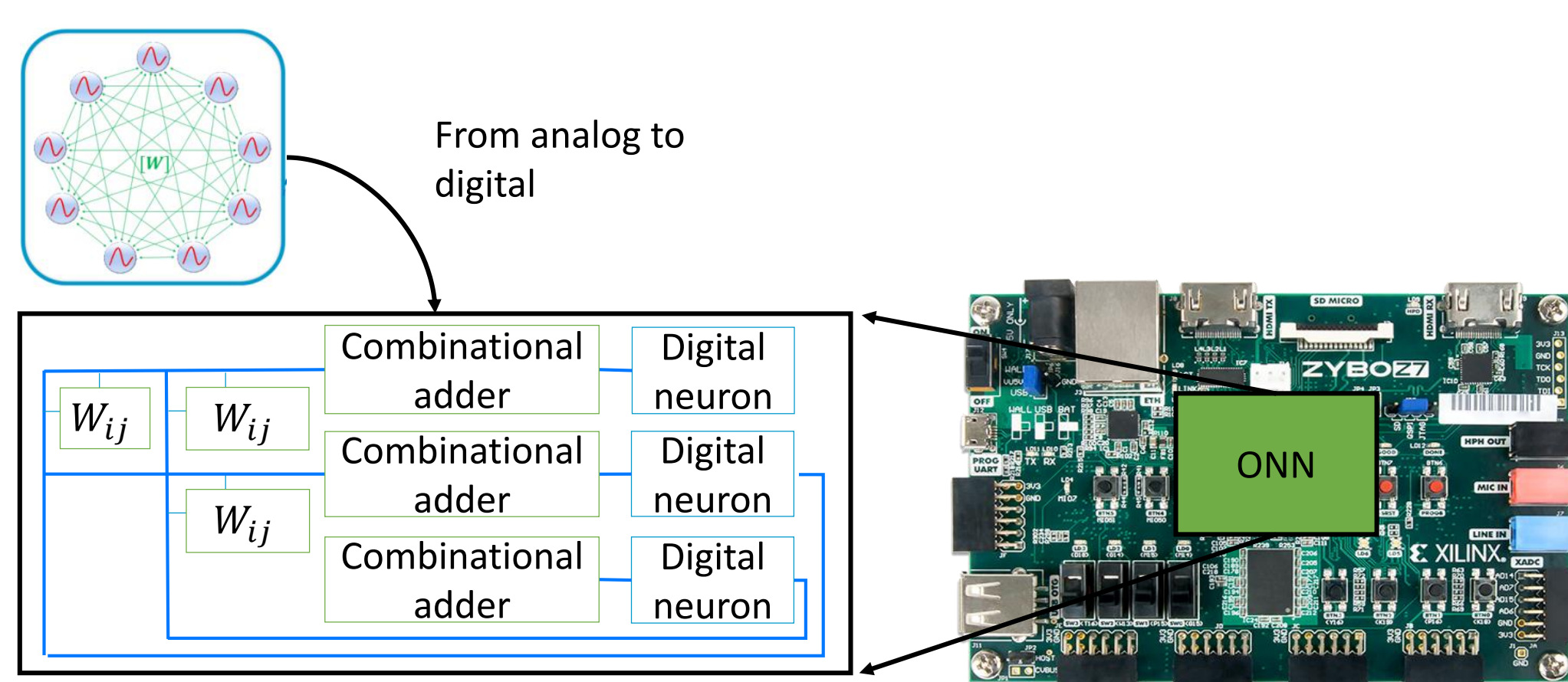


Table 1: Results and performances of the digital ONN design for multiple ONN sizes – a 5x3 ONN with 15 neurons and a 10x6 ONN with 60 neurons

ONN size	Synapses	FPGA resources		Initialization time (us)	Computation time (us)	FPS
		LUTs	Flip-Flops			
5x3	225	1,8%	0,68%	2	5,2	141000
10x6	3600	12%	2,6%	7,8	5,4	75000

### DEMONSTRATORS AND USE CASES [4]

- Digits recognition from a camera stream to an HDMI screen (10x6 ONN) [3]



Table 2: Results and performances of the digit recognition application using images from a camera stream

Results and Performances	
Frequency	37,5 MHz
ONN Computation time	5 μs – 10 μs
Accuracy (test set = 25 corrupted digits)	76 %

- Obstacle avoidance with an Arduino robot and 8 proximity sensors (5x8 ONN)

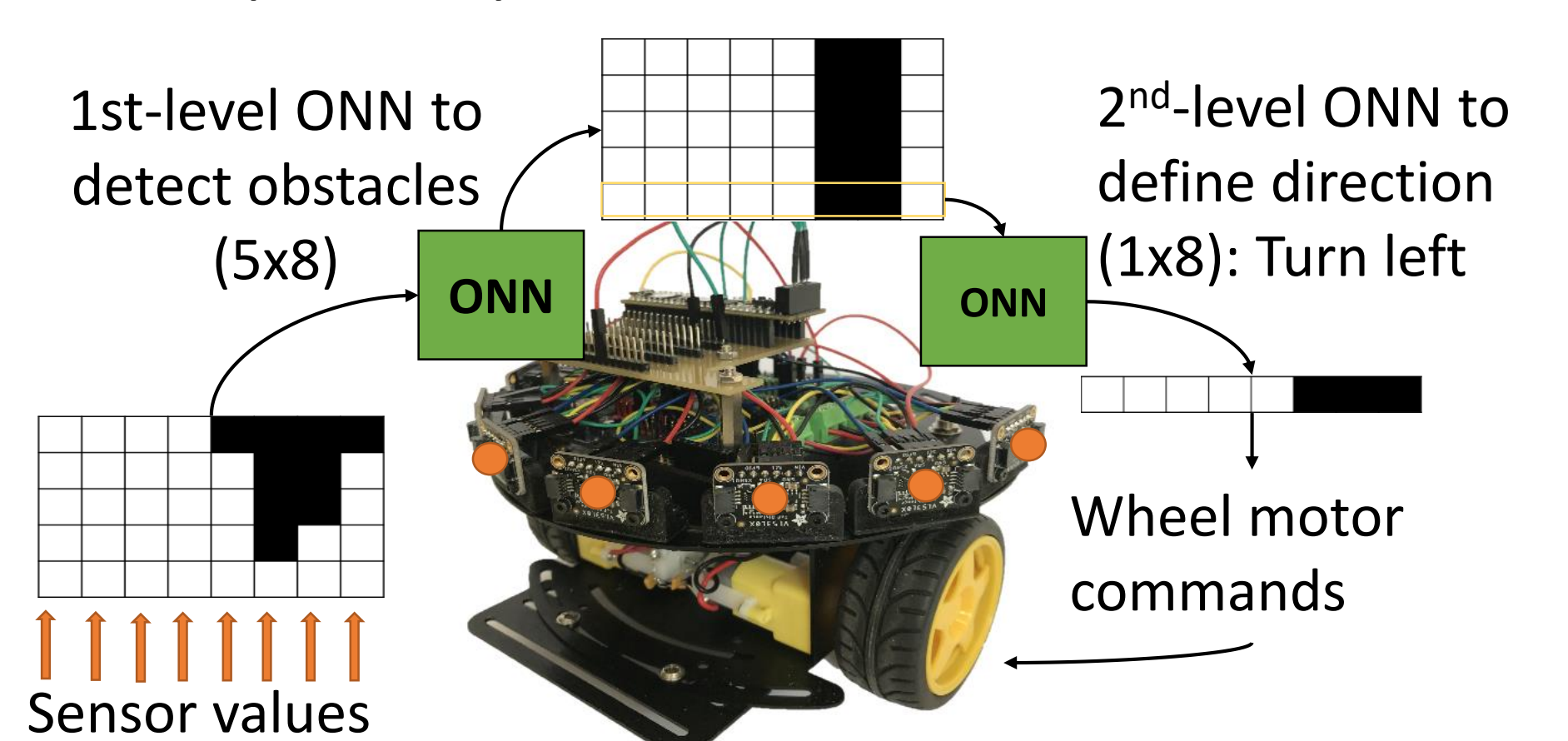


Table 3: Results and performances of obstacle avoidance application using 8 proximity sensors

ONNs	ONN 5x8	ONN 1x8
#Training Patterns	256	16
Frequency	12 MHz	12 MHz
ONN computation time	24 us	17 us
Accuracy	100 %	74 %
Full system		
FPS	40	
8-s measure time	18 ms	
Battery, Current Cons., Robot life time	6V/2850 mAh, 700 mA, 4h	

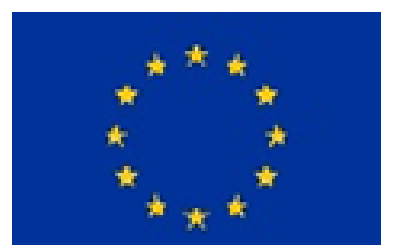
## CONCLUSION

- Development of a **proof of concept of the ONN computing paradigm** with a digital design implemented on FPGA.
- Use of the digital ONN for **image recognition** from a camera stream respecting real-time constraints.
- Combination of two digital ONNs in-a-row to perform **obstacle avoidance** on an arduino robot using 8 proximity sensors.

## REFERENCES

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- Morris, R. G. (1999). *D.O. Hebb: The Organization of Behavior*, Wiley: New York, 1949
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[www.neuronn.eu](http://www.neuronn.eu)



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