FPGA Implementation of Oscillatory Neural Networks for Artificial Intelligence Edge Computing

Madeleine Abernot, Gabriele Boschetto, Stefania Carapezzi, Corentin Delacour, Thierry Gil, Aida Todri-Sanial

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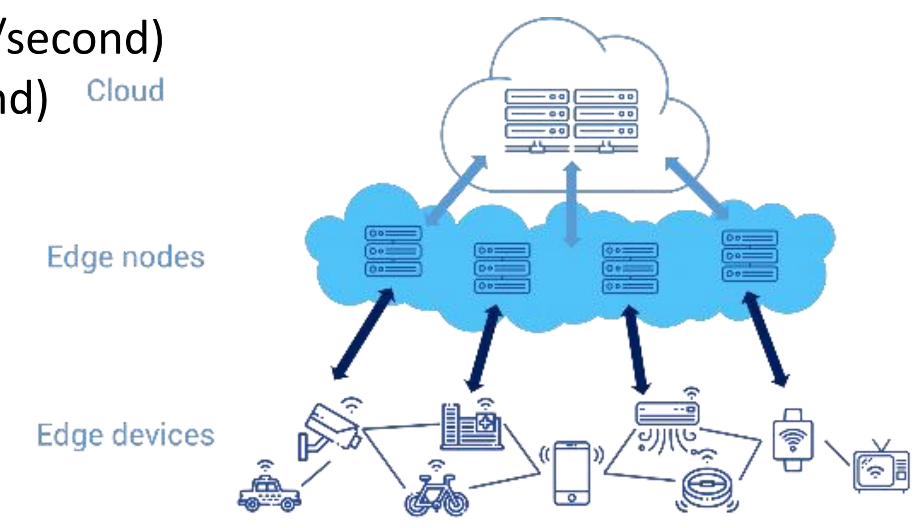
MOTIVATION AND GOALS

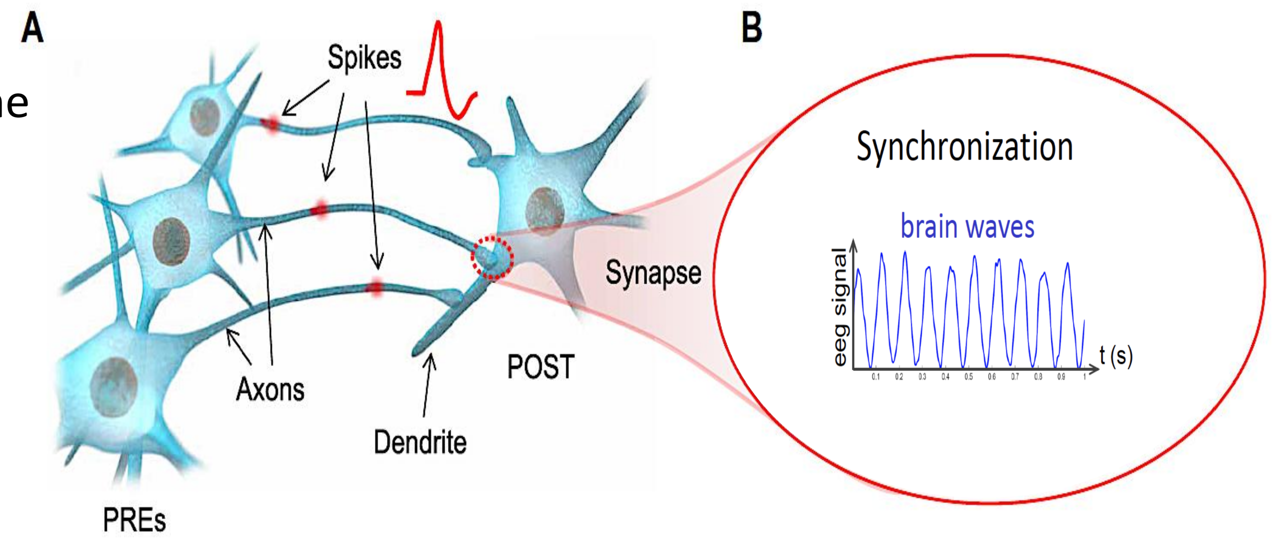
ARTIFICIAL INTELLIGENCE AT THE EDGE

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



NEUROMORPHIC COMPUTING

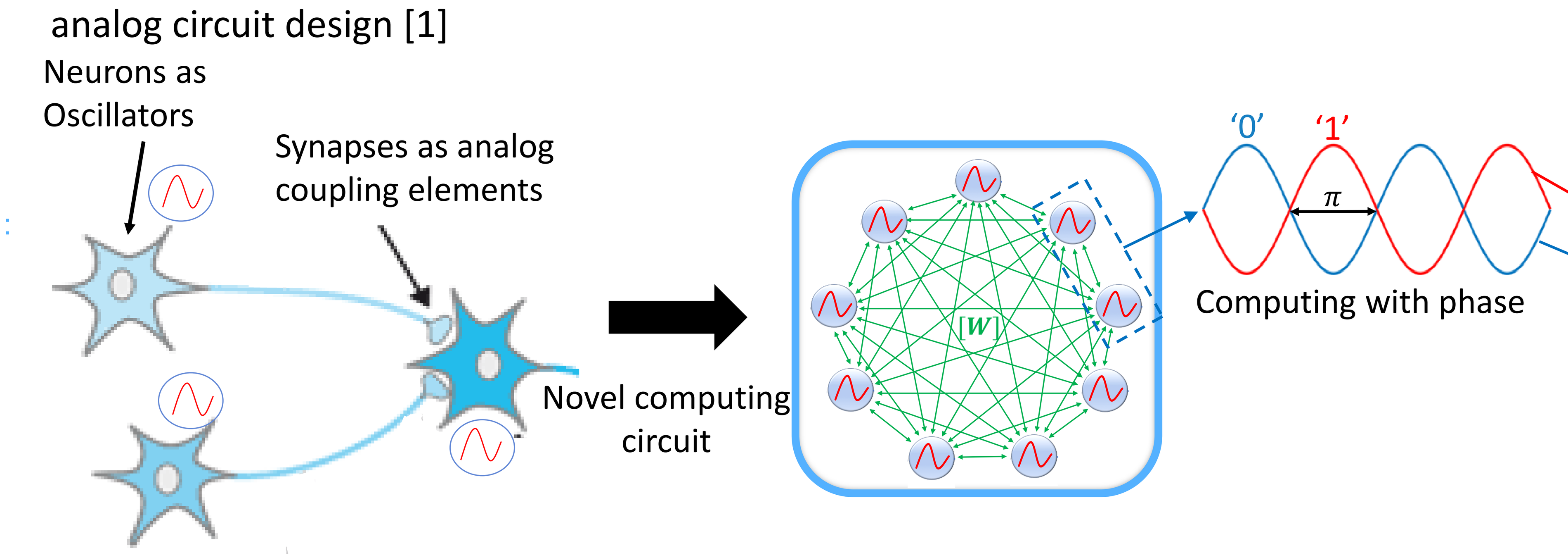
- Support online learning
- Excellent inference engine
- Low power consumption
- Scalable/low cost



OSCILLATORY NEURAL NETWORKS

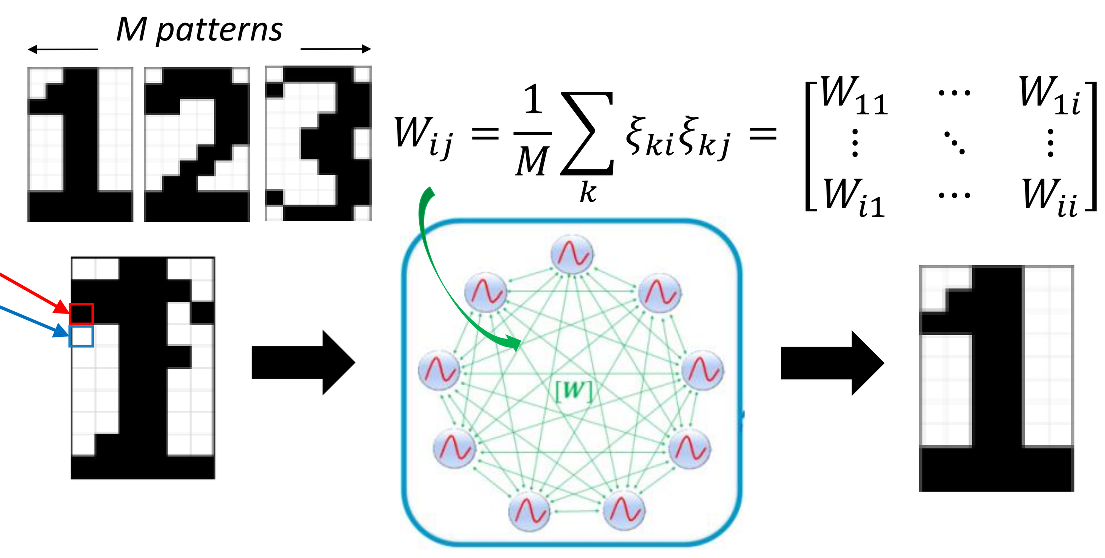
BRAIN INSPIRED COMPUTING PARADIGM

- 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.



$$W_{ij} = \frac{1}{M}\sum_k \xi_{ki}\xi_{kj} = \begin{bmatrix} W_{11} & \cdots & W_{1i} \\ \vdots & \ddots & \vdots \\ W_{i1} & \cdots & W_{ii} \end{bmatrix}$$

FPGA IMPLEMENTATION FOR DEMONSTRATORS AND USE CASES

DIGITAL ONN IMPLEMENTATION ON FPGA [3]

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

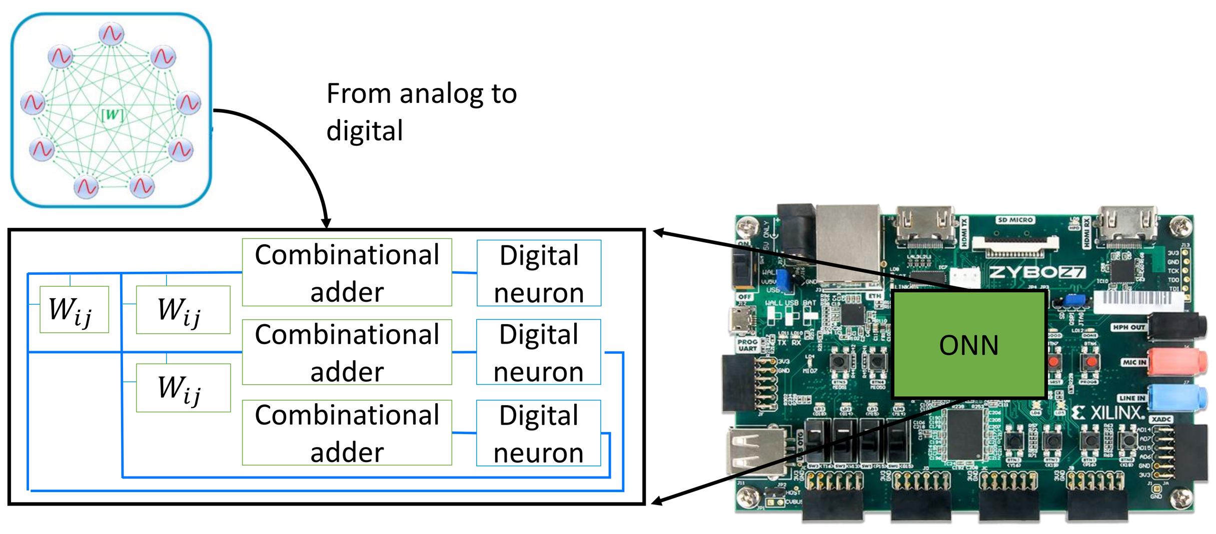


Table 1: Results and performances of the digital ONN design for multiple ONN sizes – a 5x3 ONN with 15 neurons and a 10x6 ONN with 60 neurons

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]

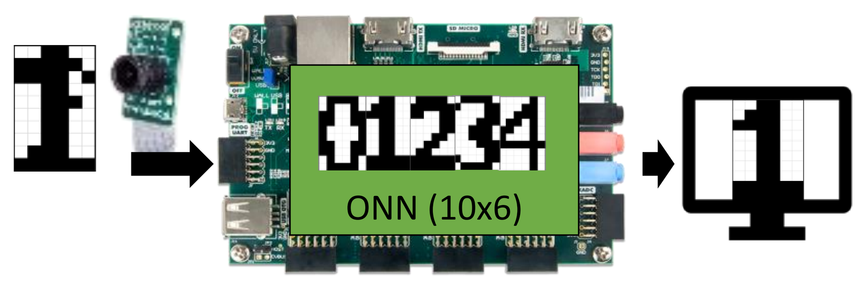


Table 2: Results and performances of the digit recognition application using images from a camera stream

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)

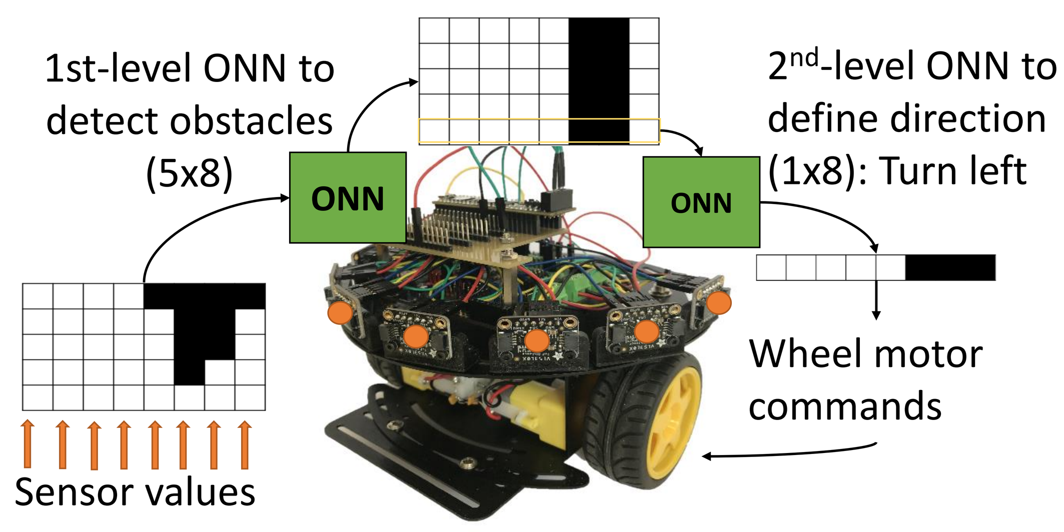


Table 3: Results and performances of obstacle avoidance application using 8 proximity sensors

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

[1] A. Todri-Sanial, et al.. EU H2020 NEURONN: Two-Dimensional Oscillatory Neural Networks for Energy Efficient Neuromorphic Computing. *EFECS*, 2020
[2] Morris, R. G. (1999). D.O. Hebb: The Organization of Behavior, Wiley: New York; 1949
[3] M. Abernot, et al. Digital Implementation of Oscillatory Neural Networks for Image Recognition Applications, *Preprint*, 2021
[4] M. Abernot, et al. Using Oscillatory Neural Network for Pattern Recognition and Mobile Robot Control. *SOPHI.A SUMMIT*, 2020

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