



**HAL**  
open science

# FPGA Implementation of Oscillatory Neural Networks for Artificial Intelligence Edge Computing

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

► **To cite this version:**

Madeleine Abernot, Gabriele Boschetto, Stefania Carapezzi, Corentin Delacour, Thierry Gil, et al..  
FPGA Implementation of Oscillatory Neural Networks for Artificial Intelligence Edge Computing.  
ACM Europe Summer school on HPC Computer Architectures for AI and Dedicated Applications,  
Aug 2021, Barcelona (Virtual), Spain. lirmm-03351242

**HAL Id: lirmm-03351242**

**<https://hal-lirmm.ccsd.cnrs.fr/lirmm-03351242v1>**

Submitted on 22 Sep 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

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

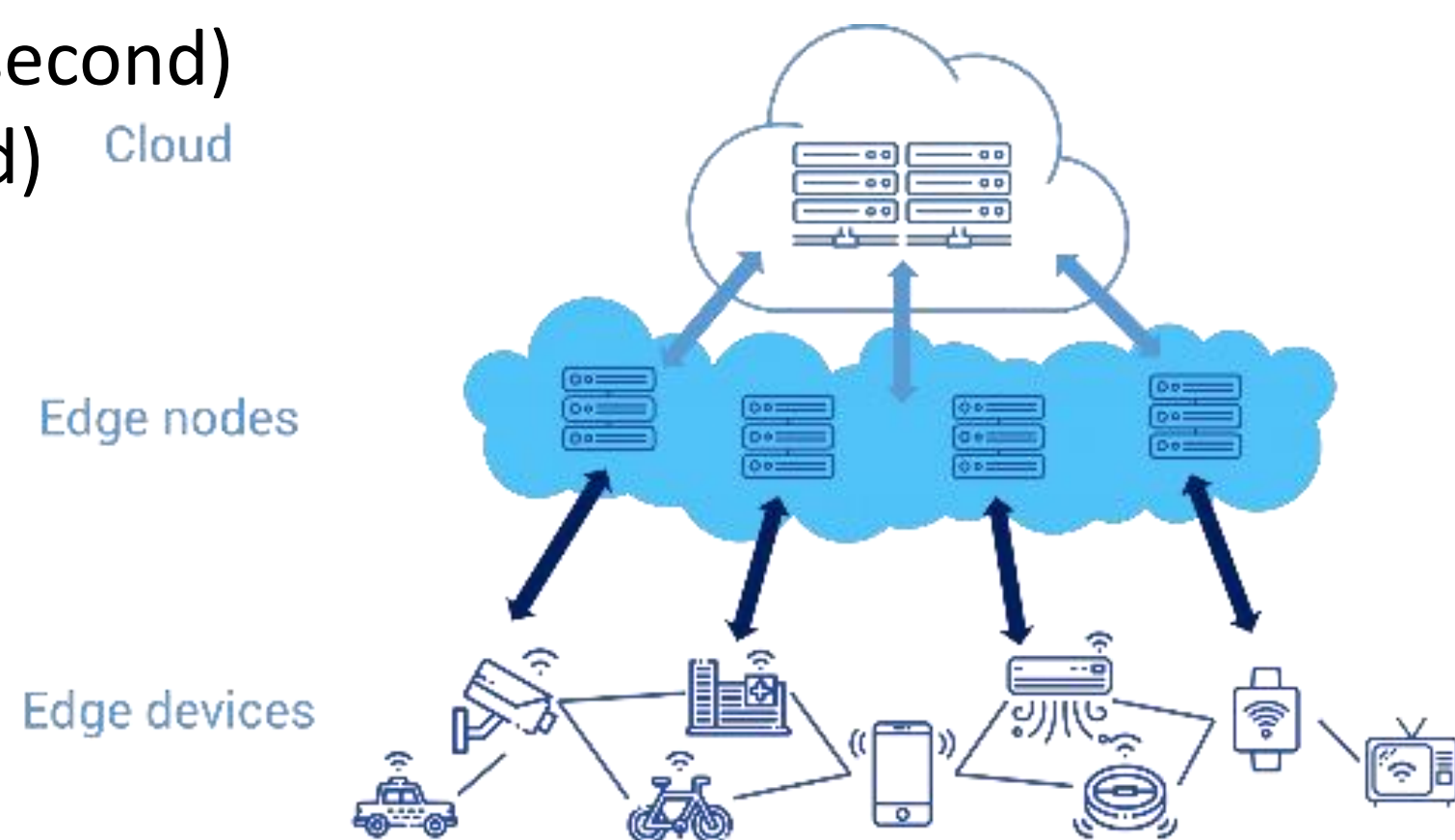


Madeleine Abernot, Gabriele Boschetto, Stefania Carapezzi, Corentin Delacour, Thierry Gil, Aida Todri-Saniai  
Microelectronics Department, LIRMM, University of Montpellier, CNRS, Montpellier, France

## MOTIVATION AND GOALS

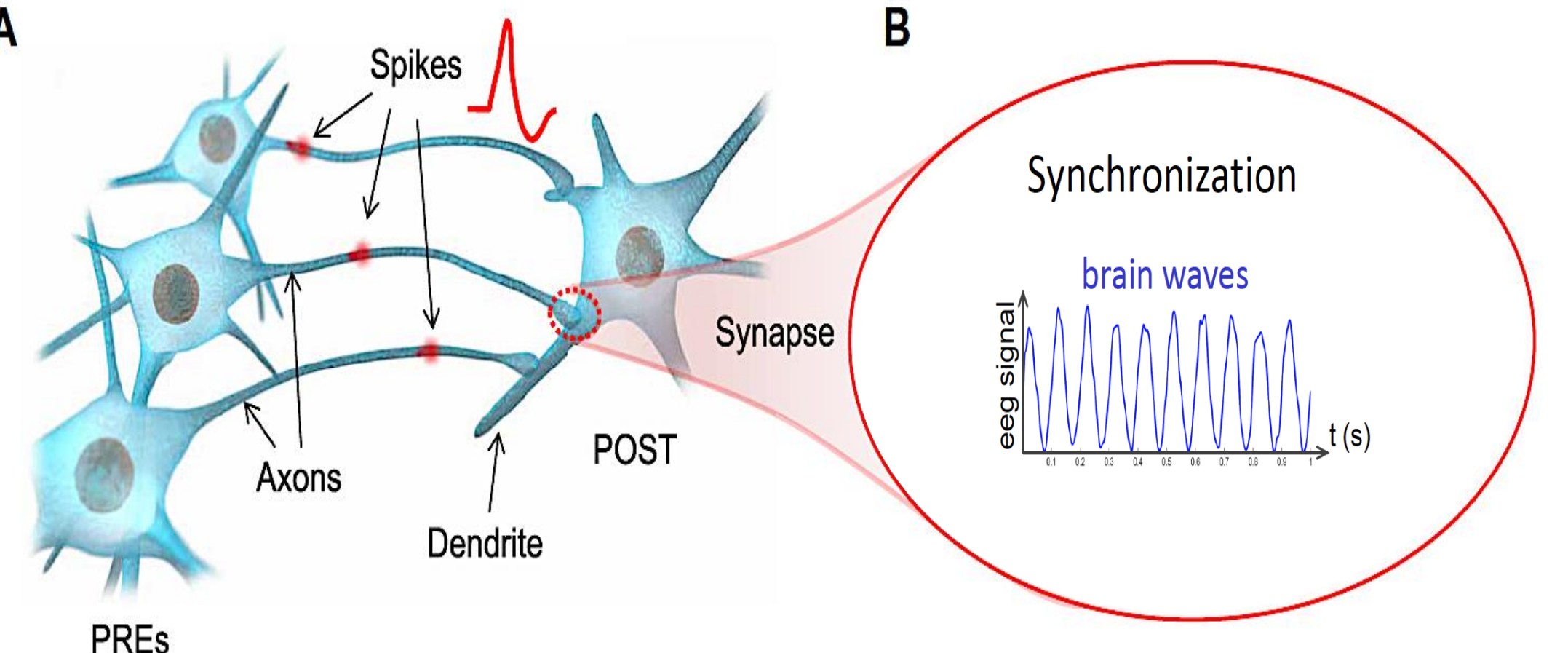
### ARTIFICIAL INTELLIGENCE AT THE EDGE

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



### NEUROMORPHIC COMPUTING

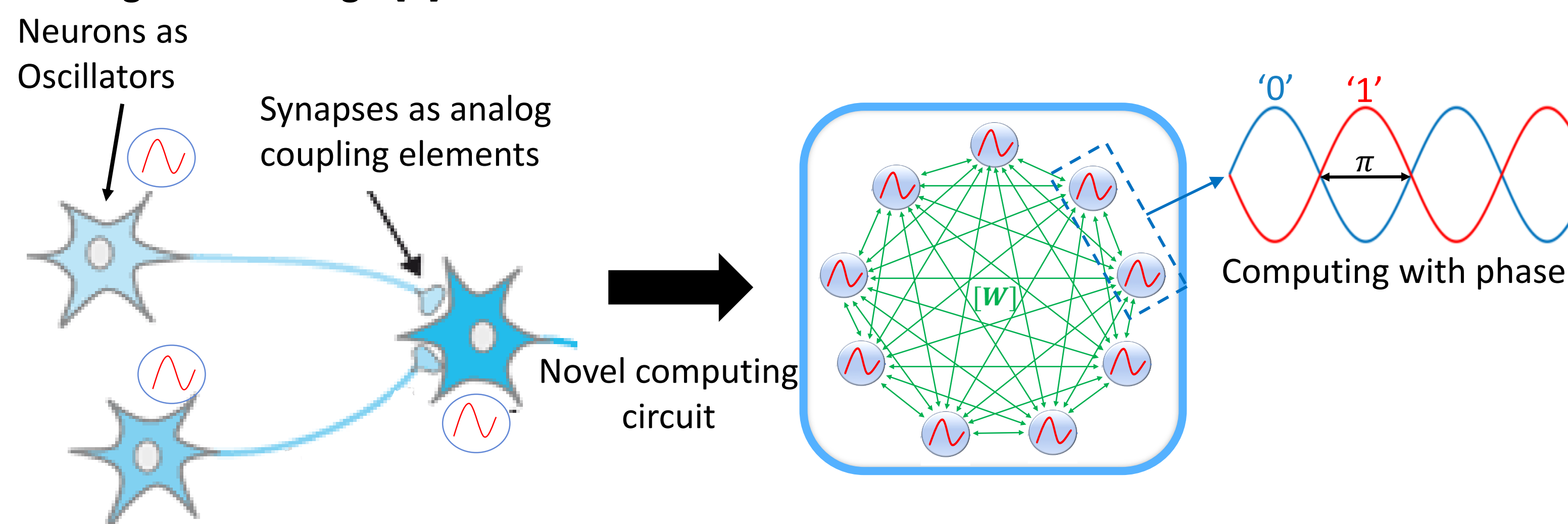
- Support online learning
- Excellent inference engine
- Low power consumption
- Scalable/low cost



## OSCILLATORY NEURAL NETWORKS

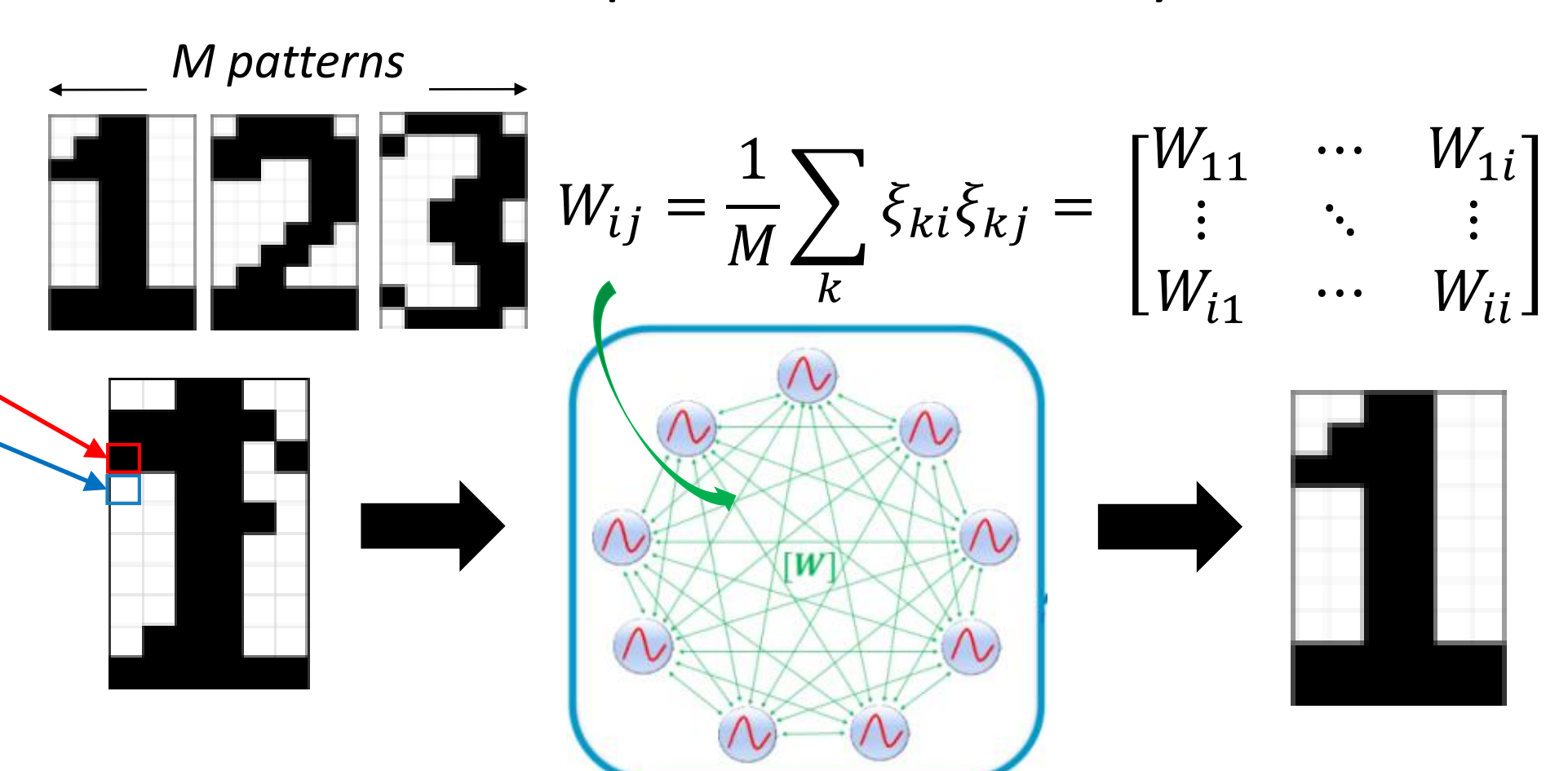
### BRAIN INSPIRED COMPUTING PARADIGM

- 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

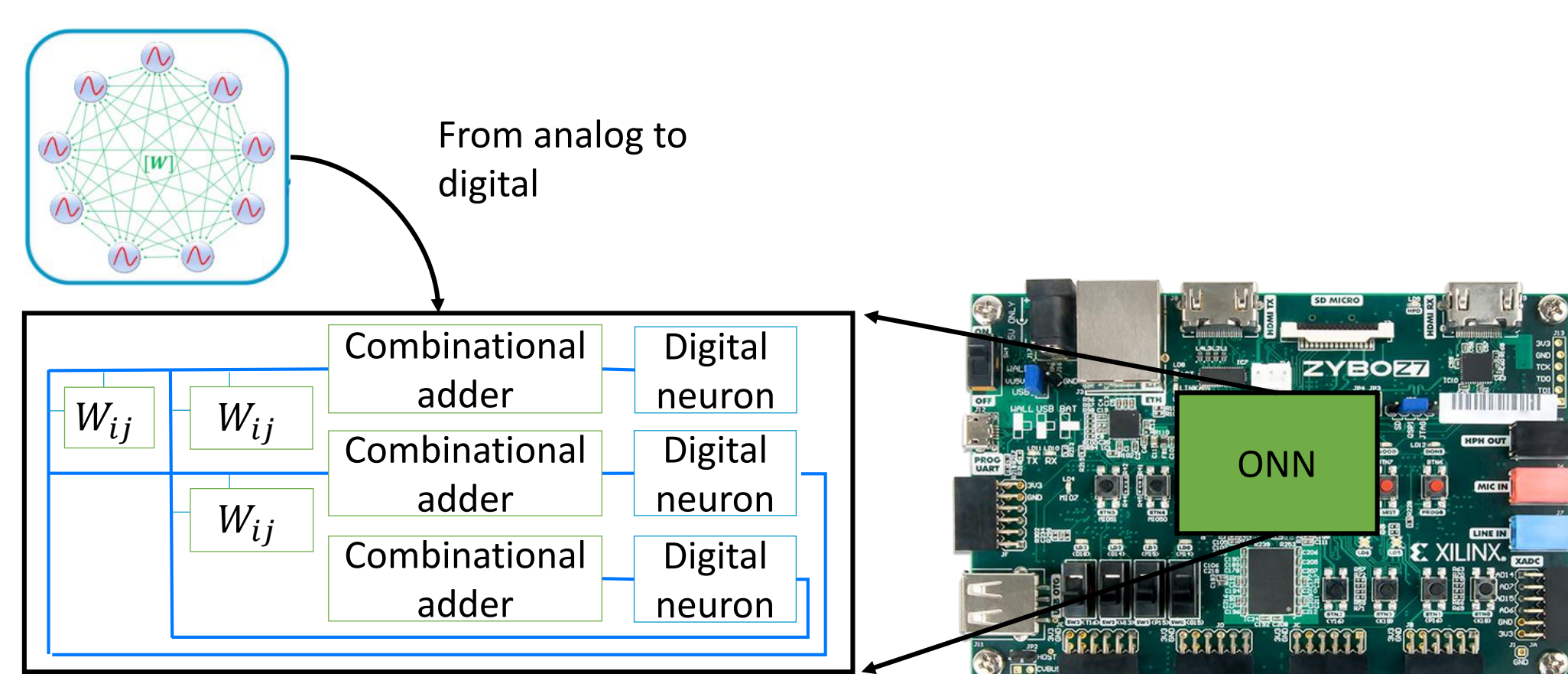


Table 1: Results and performances of the digital ONN design for multiple ONN sizes – a 5x3 ONN with 15 neurons and a 10x6 ONN with 60 neurons

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]

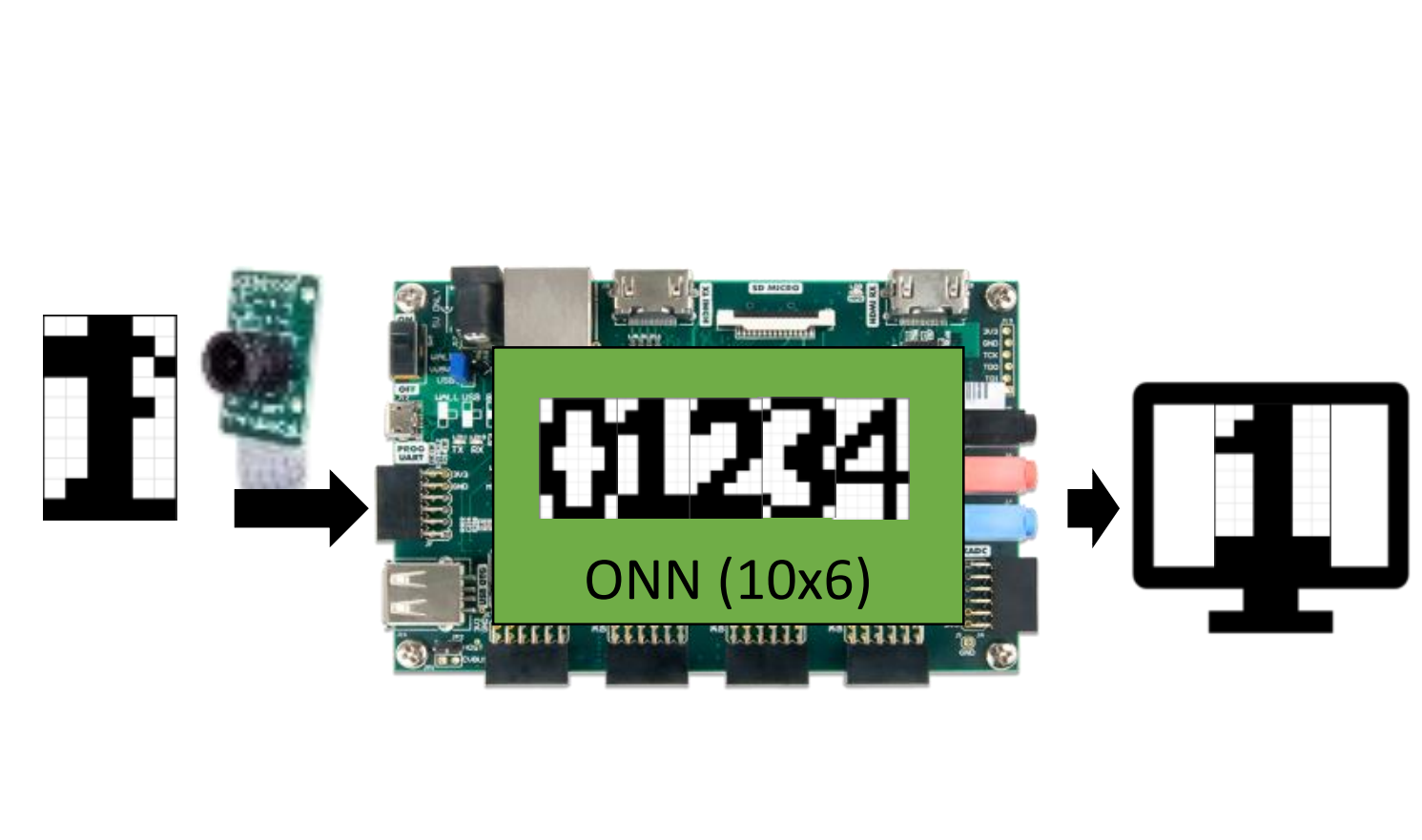


Table 2: Results and performances of the digit recognition application using images from a camera stream

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)

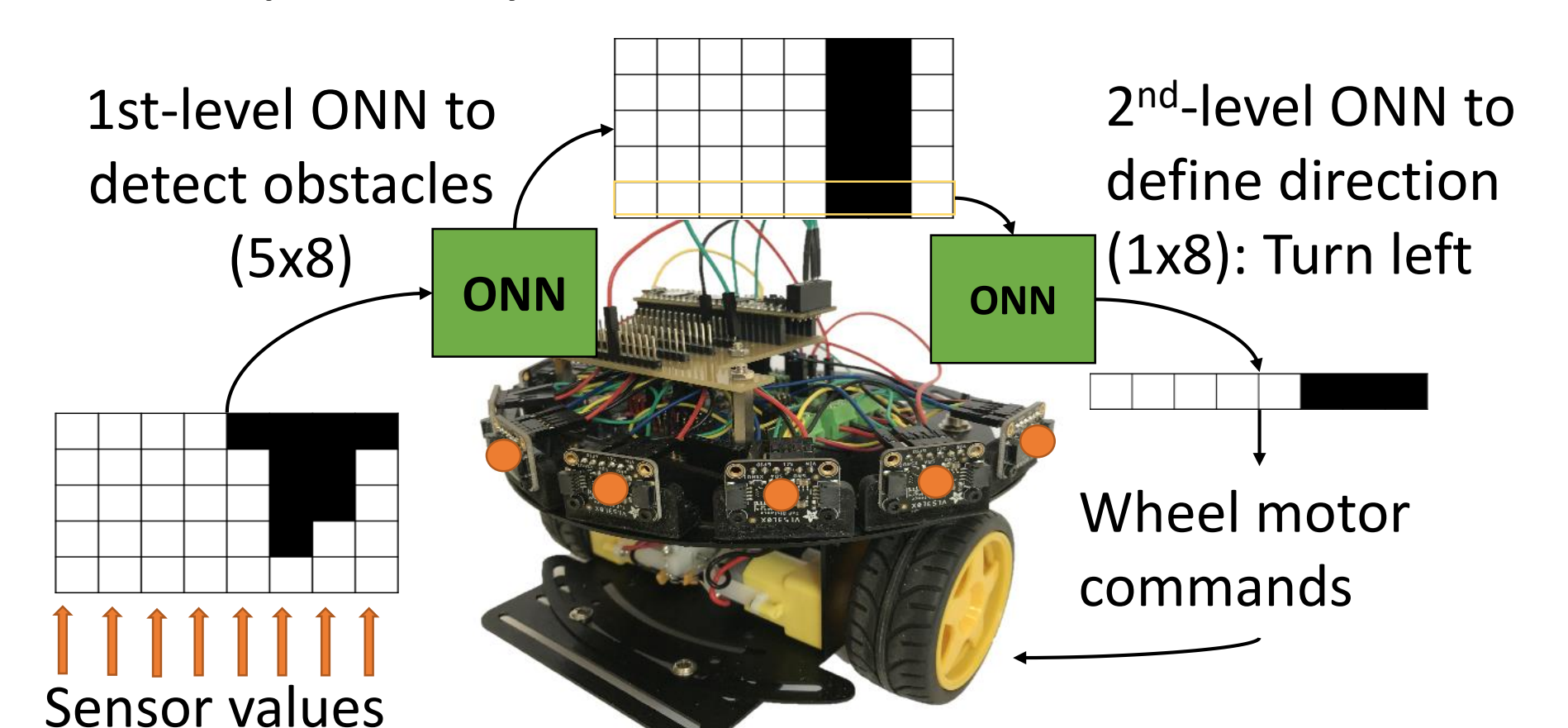


Table 3: Results and performances of obstacle avoidance application using 8 proximity sensors

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

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

## ACKNOWLEDGEMENTS AND FUNDING



The NeurONN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871501.

[www.neuronn.eu](http://www.neuronn.eu)



Project page



Project Channel



Project Channel

