The NEoterRIC project: Neuromorphic Computing and its Applications in Communications and Medical Imaging

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PDSN

At a glance …

Parallel-Distributed Systems and Networks (PDSN) from UNIWA

- PDSN was founded in 2014 (www.pdsn.uniwa.gr)
- It consists of two units
  - Parallel and Distributed Systems and Computing Unit
  - Broadband Communications and Networks Unit
- Personnel
  - 7 academics, 1 lab teaching member, 1 post-doc, 3 PhD Students
- Research outcome 2015-2020
  - > 60 publications in scientific journals & 60 publications in conference proceedings
  - Involvement in 22 research projects

http://www.pdsn.uniwa.gr

PDSN

Research fields

- Algorithmic techniques for optimization problems and applications
- Wireless Sensor Networks (WSNs), Wireless Sensor and Actuator Networks (WSANs)
- Pervasive/Assistive Environments (design methodologies/privacy and security issues)
- Optical and electronic signal processing techniques for telecom and sensing applications
- Optical switching architectures in Data Center Networks
- Optical sensing techniques
- **Optical Computing – Neuromorphic Computing (Joint Unit with CCSL from UoAegean)**

Joint Neuromorphic Research Unit

At a glance …

Neuromorphic Research Unit is based on the strong collaboration (MoU) of two laboratories

The Computer and Communication Systems Laboratory (CCSL) from the UoAegean

https://icsdweb.aegean.gr/ccsl/

Prof. Charis Mesaritakis

Parallel-Distributed Systems and Networks (PDSN) from UniWA

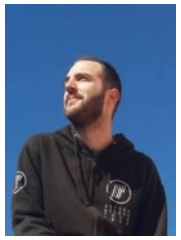
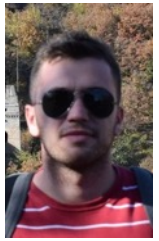
http://www.pdsn.uniwa.gr

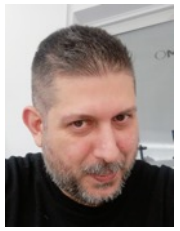
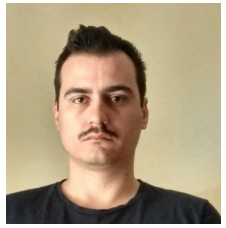
Prof. Adonis Bogris

Neuromorphic Research Unit

Personel

The joint unit consists of …

6 Ph.D candidates from diverse disciplines: photonics, machine learning, cryptography, laser, material science, telecommunications

2 faculty members with background on:

- optical communications and sensing
- photonic devices - design and characterisation
- semiconductor ultra-fast lasers
- Optical cryptography-security
- Neuromorphic computing systems

Neuromorphic Computing

What is Neuromorphic Computing ?

- *Neuromorphic computing describes analog, digital, mixed-mode analog/digital VLSI, and software systems that implement models of neural systems (for perception, classification, motor control, or multisensory integration).*
- *The implementation of neuromorphic computing on the hardware level can be realized by oxide-based memristors, spintronic memories, threshold switches, transistors and* ***photonic devices****.*
- *Neuromorphic engineering/computing is an interdisciplinary research area that takes inspiration from biology, physics, mathematics, computer science, neuroscience and electronic engineering to design* ***artificial neural systems****, whose physical architecture and design principles are based on those of* ***biological nervous systems****.*

Neuromorphic Computing

Our activities

Neuromorphic Computing

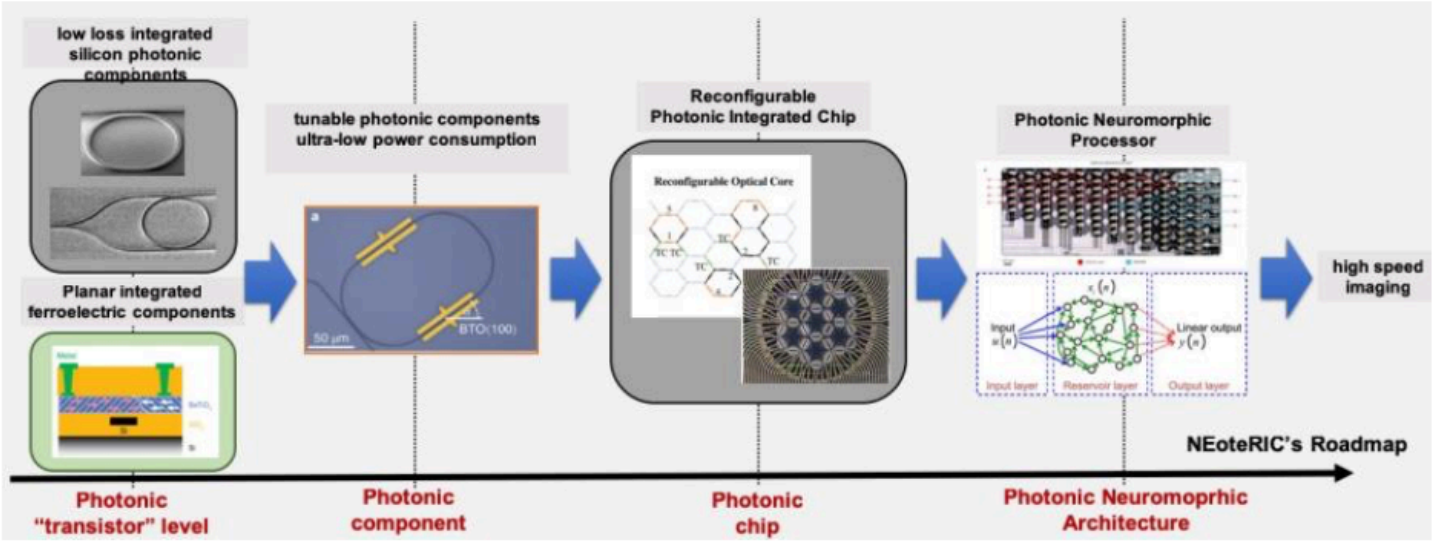
- *Design of dedicated Neuromorphic hardware (photonic-electronic) exploiting bio-inspired efficiency.*
  - *Reconfigurable Photonic neural circuits*
  - *Laser artificial neurons*
  - *FPGA/ embedded GPU Neuromorphic circuits*
- *Investigate/Implement disruptive neuromorphic architectures*
  - *Spiking CNNs*
  - *Spiking DNNs*
  - *Liquid State Machines, Reservoir Computing and Spiking RNNs*

Neuromorphic Computing

H2020 NEoteRIC Project

Neuromorphic Reconfigurable Integrated Photonic Circuits as Artificial Image Processors

- *Use of photonic integrated circuits as neural network nodes*
- *Implementation of reconfigurable circuits as a counterpart of typical FPGAs (photonic FPGAs)*

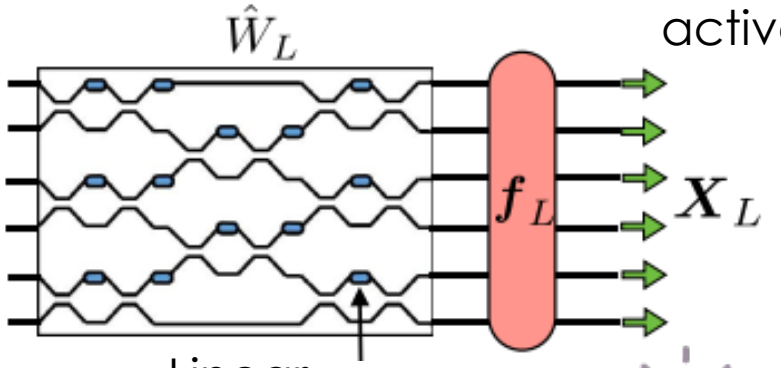


https://neoterich2020.eu/

NEoteRIC

Neuromorphic Reconfigurable Integrated Photonic Circuits as Artificial Image Processors

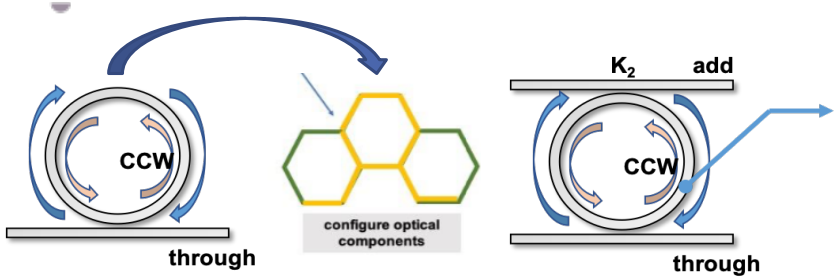
- *Linear transformations: Can be obtained in the optical domain simply by propagating light through an arrayed waveguide structure with negligible power consumption*



Non-linear activation

Linear transformation

Employ micro-ring-resonators as facet free on-chip cavities



In photonics non-linear activation is performed:

- Electro-optic (square law of the PDs)
- Computational using PDs + ADC + PC + reapply to an optical carrier
- All optical approach

An optical non-linear function can be achieved by exploiting effects such as TPA, Kerr Effect etc.

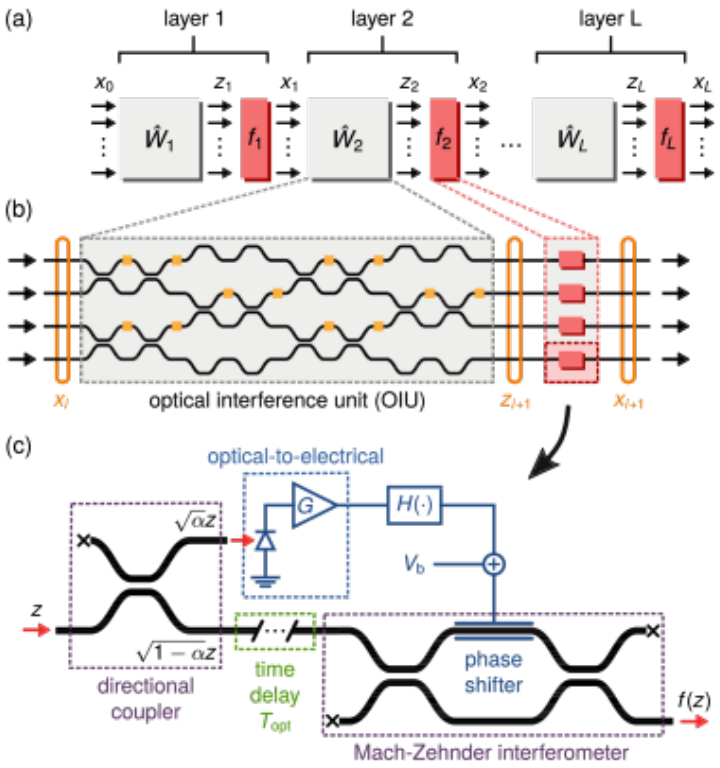
- Utilize a cavity so at to enhance these effects
- Utilize the proper material
- employ the necessary power

Neuromorphic Computing

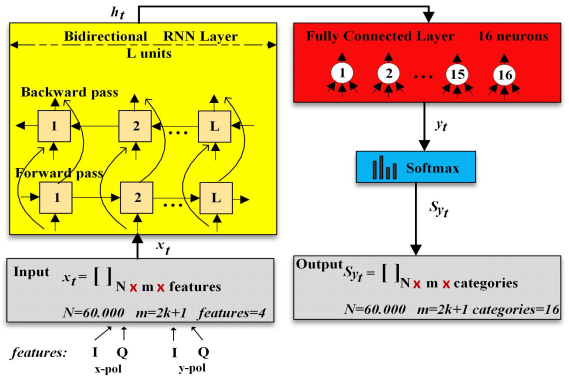
H2020 NEoteRIC Project

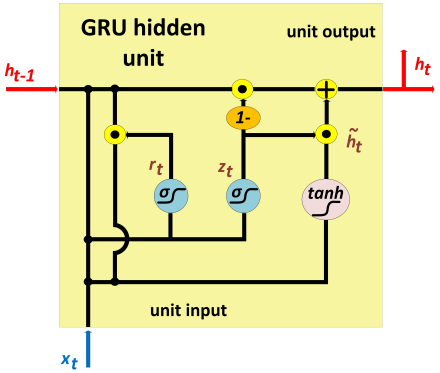
Basic models that will be implemented with photonic nodes

Feedforward Neural Networks

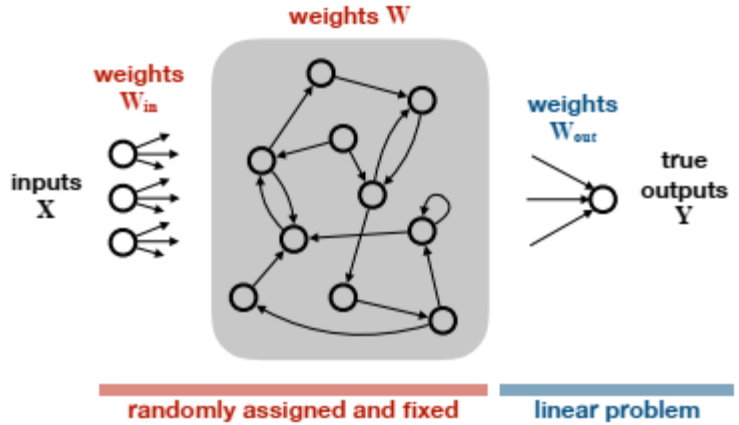


Recurrent Neural Networks





Neuromorphic Computing Paradigms (Reservoir Computing)



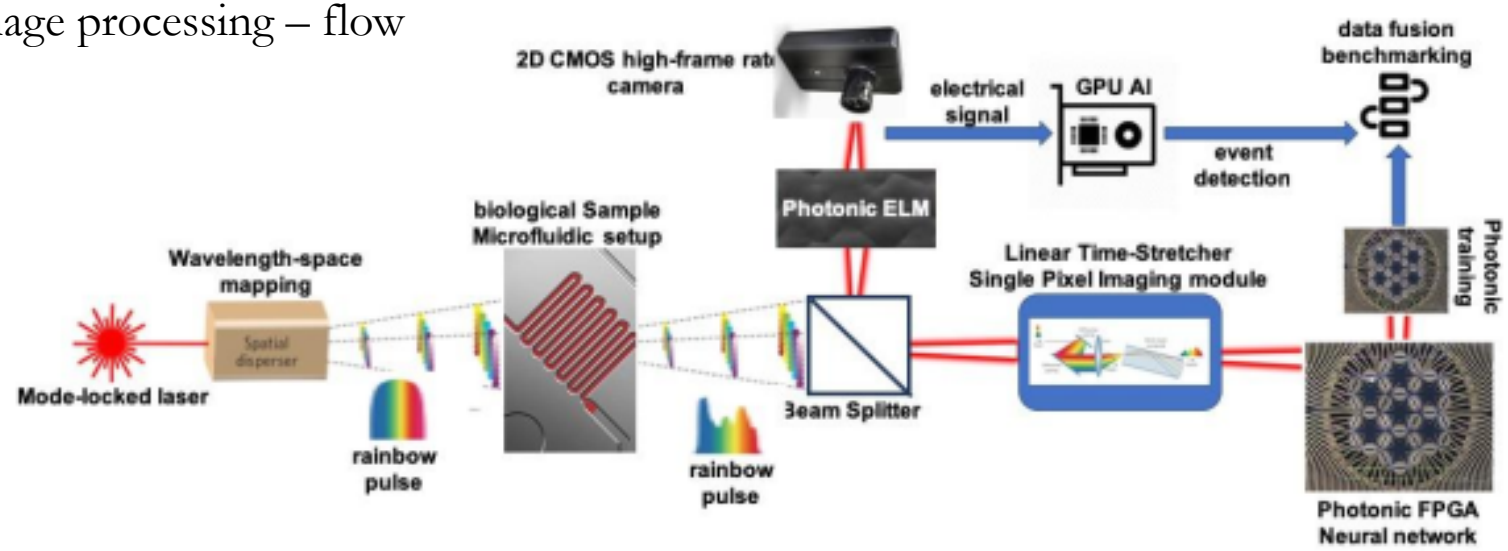
One of the most appropriate networks for hardware implementation: Only the output layer is trained

Applications

Medical Imaging

H2020 NEoteRIC Project: Demonstration of reconfigurable photonic neuromorphic computing networks and their use in high-speed medical imaging

- Dispersive-Fourier Imaging
- Use of neuromorphic photonics to achieve fast image processing – flow cytometry



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NEoteRIC

Applications

Trustworthy and High Efficiency Edge Computing Devices

Security and Intelligence at the hardware layer

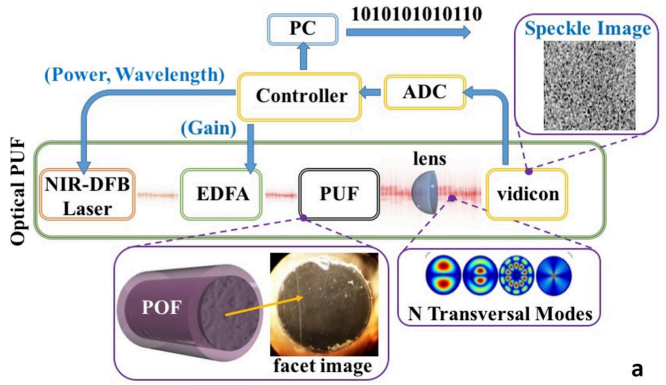
- Use of photonic devices as physical unclonable functions, random number generators, chaotic encryption units, etc.
- These functionalities can be combined with neuromorphic computing, thus enabling the concept of crypto-neuromorphic processors for low cost deployment of Internet of Everything Intelligent and Trusted Systems.

SCIENTIFIC REPORTS

OPEN

Physical Unclonable Function based on a Multi-Mode Optical Waveguide

Charis Mesaritakis[1], Marialena Akriotou[2], Alexandros Kapsalis[1], Evangelos Grivas[1], Charidimos Chaintoutis[2], Thomas Nikas[2] & Dimitris Syvridis[2]

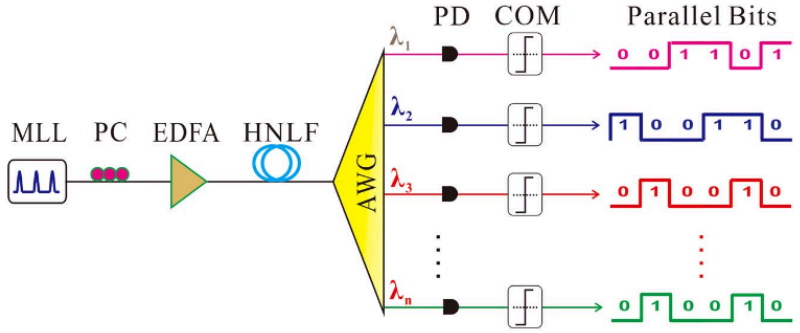


2446 Vol. 44, No. 10 / 15 May 2019 / Optics Letters Letter

Optics Letters

Parallel optical random bit generator

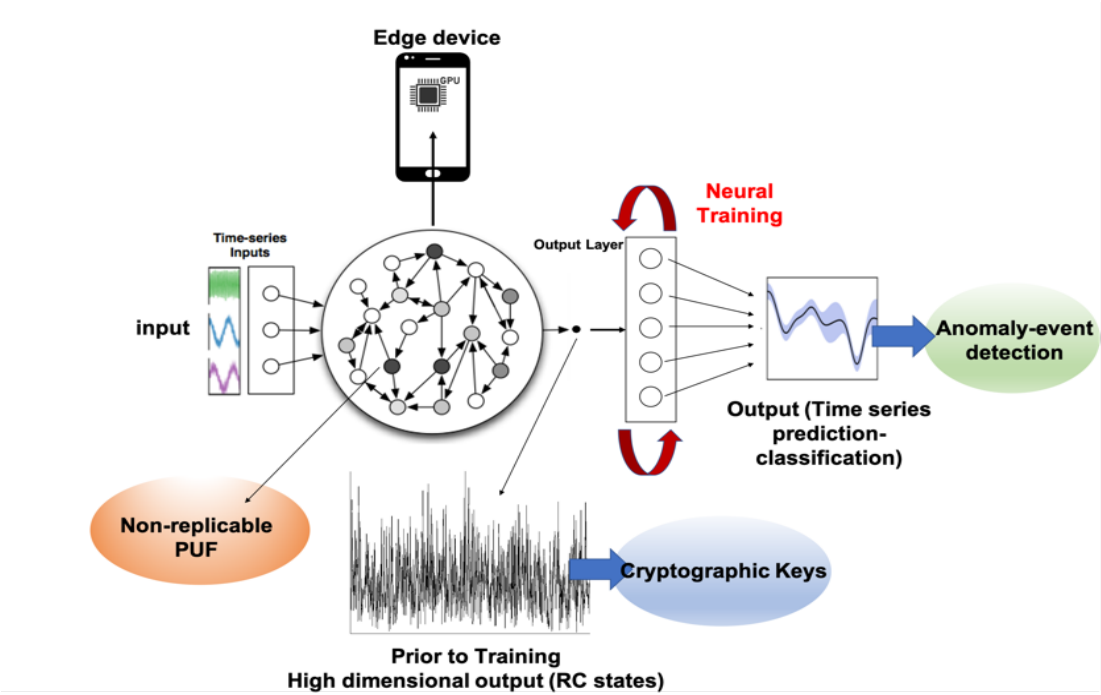
Pu Li,[1,2,3,4] Kunying Li,[1,2] Xiaomin Guo,[1,2] Yanqiang Guo,[1,2] Yiming Liu,[4] Bingjie Xu,[4] Adonis Bogris,[5] K. Alan Shore,[6] and Yuncai Wang[1,2,*]

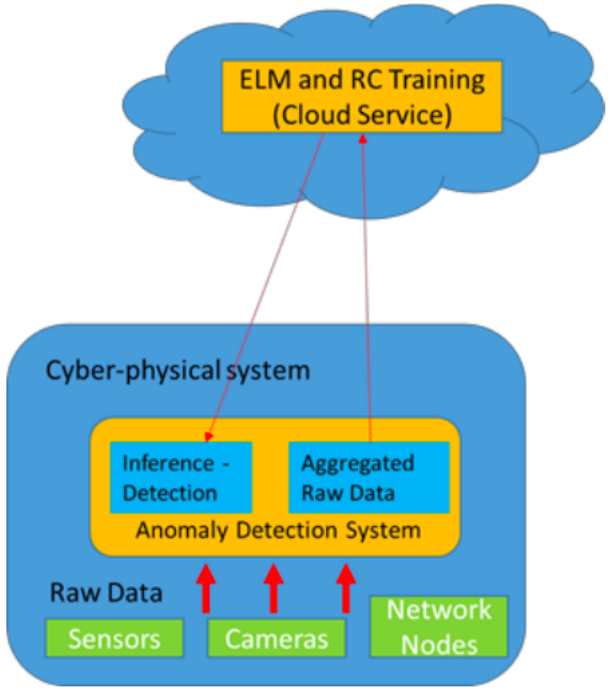


Applications

Trustworthy and High Efficiency Edge Computing Devices

Distributed neuromorphic computing – less complex recurrent neural network models based on NC paradigms such as Extreme Learning Machine (ELM) and RC





Neuromorphic Computing

Next Steps

- *To upgrade the practicality of these systems towards large scale networks*
- *To combine typical software based neural network models with hardware accelerators based on neuromorphic computing*
- *To propose and deploy neuromorphic computing solutions that are more compatible with IoT and edge computing applications*
- *To exploit the unique hardware properties of neuromorphic nodes in the direction of using the same device as processor and authentication unit at the same time.*