

XXXII Cycle

# **Offline and online neural networks applied** to pattern recognition of big data and loT (Internet of things) sensors data Vincenzo Randazzo

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## **Research context and motivation**

- Data mining is more and more facing the extraction of meaningful information from big data (e.g. medical records). Most Neural Networks techniques work offline. However, the possibility of using a technique working in real time is very important, because it allows not only having a very fast response, but also tracking non-stationary data distributions (e.g. time-varying data manifolds). This can be applied, for example, to all applications of real time pattern recognition, such as medical data acquired in real time or fault diagnosis.
- Neural network approaches fall in two categories: **forgetting** and **lifelong learning**. Forgetting networks, as DSOM, have fixed 15 number of neurons and constant learning 10rates. They are used only if the most recent information is of interest as they lose the past representation.
  - On the contrary, if the network automatically

## **Novel contributions**

- G-EXIN neural network: online, data driven (self-organizing) and incremental (aging & pruning).
- Two distinct types of links: Edges (track stationarity), Bridges (track non-stationarity).



finds the number of units, as a function of -15the complexity of the problem, it creates new neurons each time the distribution changes.



#### Addressed research questions/problems

- Real-time pattern recognition on evolving continuous data stream
- Novelty and Outlier (i.e. disease/fault) detection
- Track non-stationary distribution

How a learning system can adapt to new information without corrupting or forgetting previously learned information?



# Submitted and published works

- G. Cirrincione, V. Randazzo and E. Pasero, "Growing Curvilinear Component Analysis (GCCA) for Dimensionality Reduction of Nonstationary Data" in Multidisciplinary Approaches to Neural Computing, Springer International Publishing, 2018, pp. 151-160.
- Kumar, R.R., Randazzo, V., Cirrincione, G., Cirrincione, M., Pasero, E., "Analysis of stator faults in induction machines using growing curvilinear component analysis", in 2017 20th International Conference on Electrical Machines and Systems (ICEMS), Sydney (Australia), 2017.
- V. Randazzo, E. Pasero and S. Navaretti, "VITAL-ECG: A portable wearable hospital", in 2018 IEEE Sensors Applications Symposium (SAS), Seoul, 2018, pp. 1-6.
- Cirrincione, G., Randazzo, V., Pasero, E., "The Growing Curvilinear Component Analysis (GCCA) neural network", in Neural Networks, 103, 2018, pp. 108-117, Elsevier Ltd.
- Randazzo, V., Cirrincione, G., Ciravegna, G., Pasero, E., "Nonstationary topological learning with bridges and convex polytopes: the G-EXIN neural network", in 2018 International Joint Conference on Neural Networks (IJCNN), Rio de Janeiro (Brasil), 2018, pp. 1-6.
- G. Cirrincione, M. Cirrincione, D. Guilbert, A. Mohammadi and V. Randazzo, "Power Switch Open-Circuit Fault Detection in an Interleaved DC/DC Buck Converter for Electrolyzer Applications by Using Curvilinear Component Analysis", in 2018 21st International Conference on Electrical Machines and Systems (ICEMS), Jeju (South Korea), 2018, pp. 2221-2225. G. Cirrincione, G. Ciravegna, P. Barbiero, V. Randazzo and E. Pasero, "The GH-EXIN neural network for hierarchical clustering", in Neural Networks, 121, 2020, pp. 57-73, Elsevier Ltd. V. Randazzo, J. Ferretti and E. Pasero, "ECG WATCH: a real time wireless wearable ECG", in 2019 IEEE International Symposium on Medical Measurements and Applications (MeMeA), Istanbul (Turkey), 2019, pp. 1-6. Randazzo, V., Cirrincione, G., Pasero, "A Neural Based Comparative Analysis for Feature Extraction from ECG Signals", in Neural Approaches to Dynamics of Signal Exchanges, 151. In press Kumar, R.R., Randazzo, V., Cirrincione, G., Cirrincione, M., Pasero, E., "Growing Curvilinear Component Analysis (GCCA) for Stator Fault Detection in Induction Machines" in Neural Approaches to Dynamics of Signal Exchanges, 151. *In press* R. Ferrero, M. Ghazi Vakili, E. Giusto, M. Guerrera and V. Randazzo, "Ubiquitous fridge with natural language interaction", in 2019 IEEE International Conference on RFID Technology and Applications (RFID-TA), Pisa (Italy). In press V. Randazzo, G. Cirrincione and E. Pasero, "A new unsupervised neural approach to stationary and non-stationary data analysis", in Advances in Data Science: Methodologies and Applications, Springer. Accepted J. Ferretti, V. Randazzo, G. Cirrincione and E. Pasero, "1-D Convolutional Neural Network for ECG Arrhythmia Classification", Springer Singapore. Accepted V. Randazzo, G. Cirrincione, A. Paviglianiti, F.C. Morabito and E. Pasero, "Neural feature extraction for the analysis of Parkinsonian patient handwriting", Springer Singapore. Accepted V. Randazzo, J. Ferretti and E. Pasero, "A Wearable Smart Device to Monitor Multiple Vital Parameters – VITAL ECG", in Electronics, MDPI. Submitted V. Randazzo, J. Ferretti and E. Pasero, "A novel wearable atrial fibrillation detector", in IEEE Transactions on Instrumentation and Measurement, IEEE. Submitted Kumar, R.R., Randazzo, V., Cirrincione, G., Cirrincione, M., Pasero, "Induction Machines Stator Fault Tracking using the Growing Curvilinear Component Analysis", in IEEE Access. In progress V. Randazzo, G. Cirrincione, G. Ciravegna and E. Pasero, "The G-EXIN neural network", in IEEE Transactions on Neural Networks and Learning Systems, IEEE. In progress

# Adopted methodologies

- Deep theoretical analysis of offline neural networks to understand which are the ideas at the base of their creation in order to define a novel approach for the implementation of a new class of neural networks that will learn and work on real time (online) data.
- New threshold mechanism to take into account neuron neighborhood shape and to have 2. a more accurate representation, considering also time-efficiency constraint.
- Reducing user dependent parameters. G-EXIN requires only three:  $\alpha$  for scaling the 3. learning rate,  $\sigma$  for modulating SCL and  $age_{max}$  for edge pruning.
- Non-stationarity and outlier detection mechanism for lifelong learning.



#### **Future work**

## Submitted and published patents

- "Sound Bubble", Metodo di processo digitale di un segnale audio e relativo sistema, Ref: 2017-017-01
- "Sound Bubble", Metodo di processo digitale di un segnale audio e relativo sistema per uso in un impianto produttivo con macchinari, Ref: 2017-046

- Automatic parameter setup.
- The  $age_{max}$  global parameter will become local, in order to fine tune the pruning.
- A thorough analysis of bridges has still to be carried out.
- Application to medical non-stationary signals, such as ECG or PPG.
- Hardware implementation of G-EXIN

# **Innovation Program Awards**

- Innovation for Change POLITO, CERN & SAFM face the Future, Ph.D. Course on Innovation -Entrepreneurship - Value Creation: **SoundBubble: A flawless work environment**, 1° prize
- **European Innovation Academy** Extreme Entrepreneurship Program, From an idea to a tech start-up in 15 days, CardioGuard, TOP 10 team

### List of attended classes

- 01RYHRV Disruption Tolerant Networks: Routing Algorithms and Protocols 04/07/2017, (6 CFU)
- 01QSAIU Heuristics and metaheuristics for problem solving: new trends and software tools -06/07/2017, 20 hours (4 CFU)
- 02RHQRV Intellectual Property Rights, Technology Transfer and Hi-tech Entrepreneurship (Theoretical course + [...] – 17/07/2017, 46 hours (9 CFU)
- 01MNFIU Parallel and distributed computing 06/07/2017, 25 hours (5 CFU)
- 01RQXRV Pattern recognition and neural networks (didattica di eccellenza) 05/05/2017, (8 CFU)
- 01SHCRV Unsupervised neural networks (didattica di eccellenza) 09/04/2018, (6 CFU)
- 01SFURV Programmazione scientifica avanzata in matlab 27/3/2019, (6 CFU)
- 01TAGIU Ubiquitous computing 21/5/2019, (4 CFU)
- 01TBXRV Vision fundamentals in service robotics 23/5/2019, (4 CFU)
- 01TEVRV Deep learning (didattica di eccellenza) 04/6/2019, (6 CFU)



#### POLITECNICO DI LORINO



#### **Electrical, Electronics and**

#### **Communications Engineering**