COPPE
UFRJ

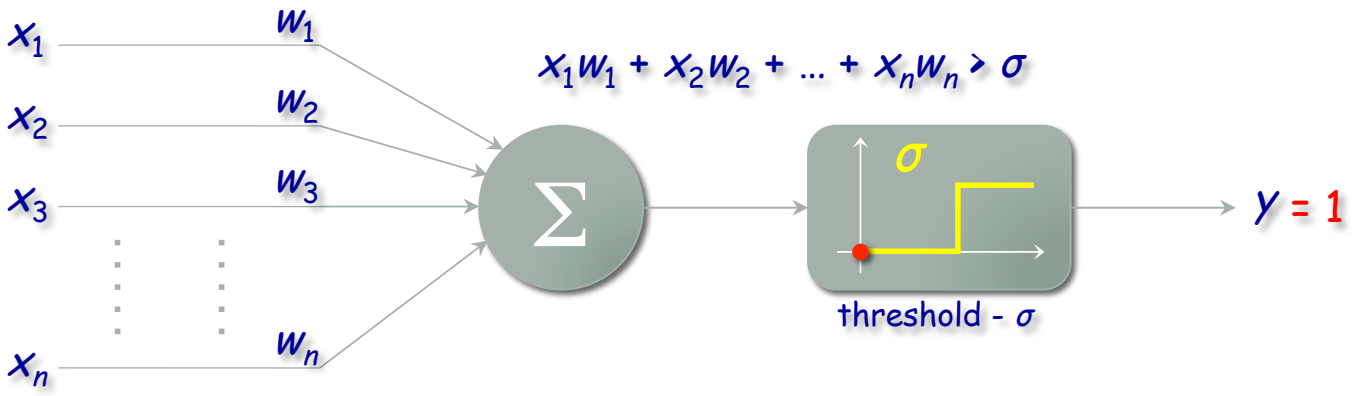
Weightless Neural Networks

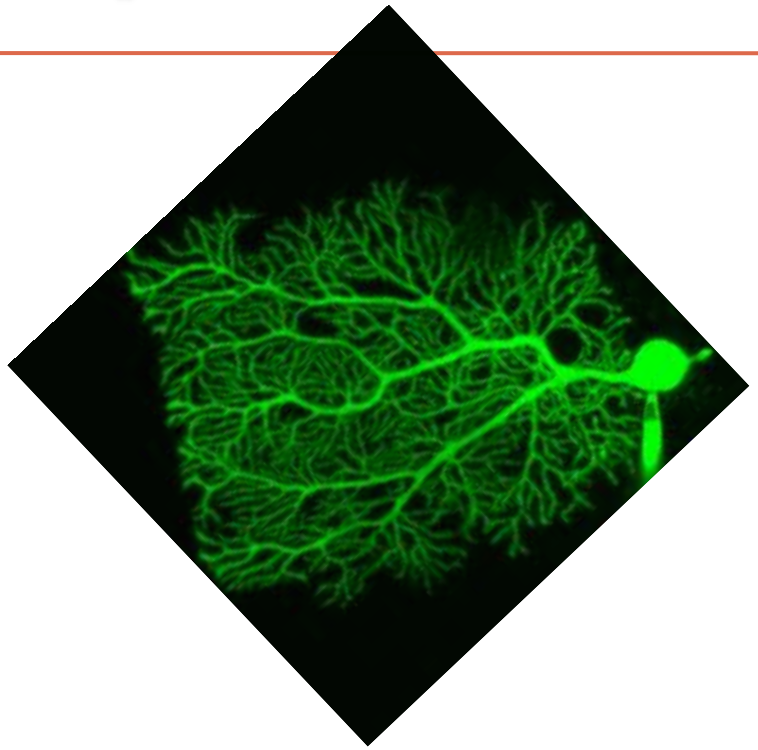
Felipe M. G. França
Systems Engineering and Computer Science Program
Universidade Federal do Rio de Janeiro

felipe@cos.ufrj.br
felipe@ieee.org

COPPE
UFRJ

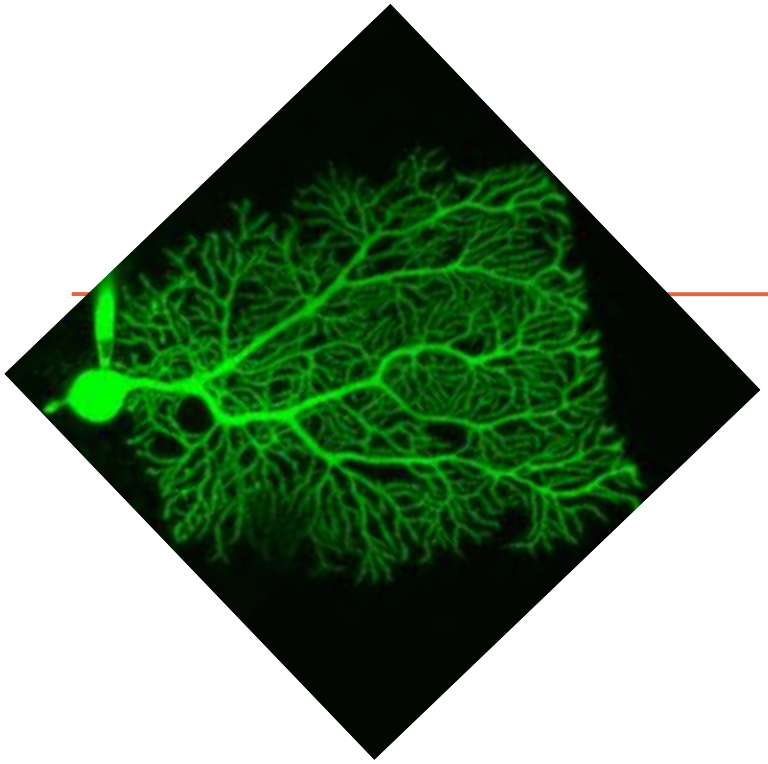
The McCulloch and Pitts neuron model



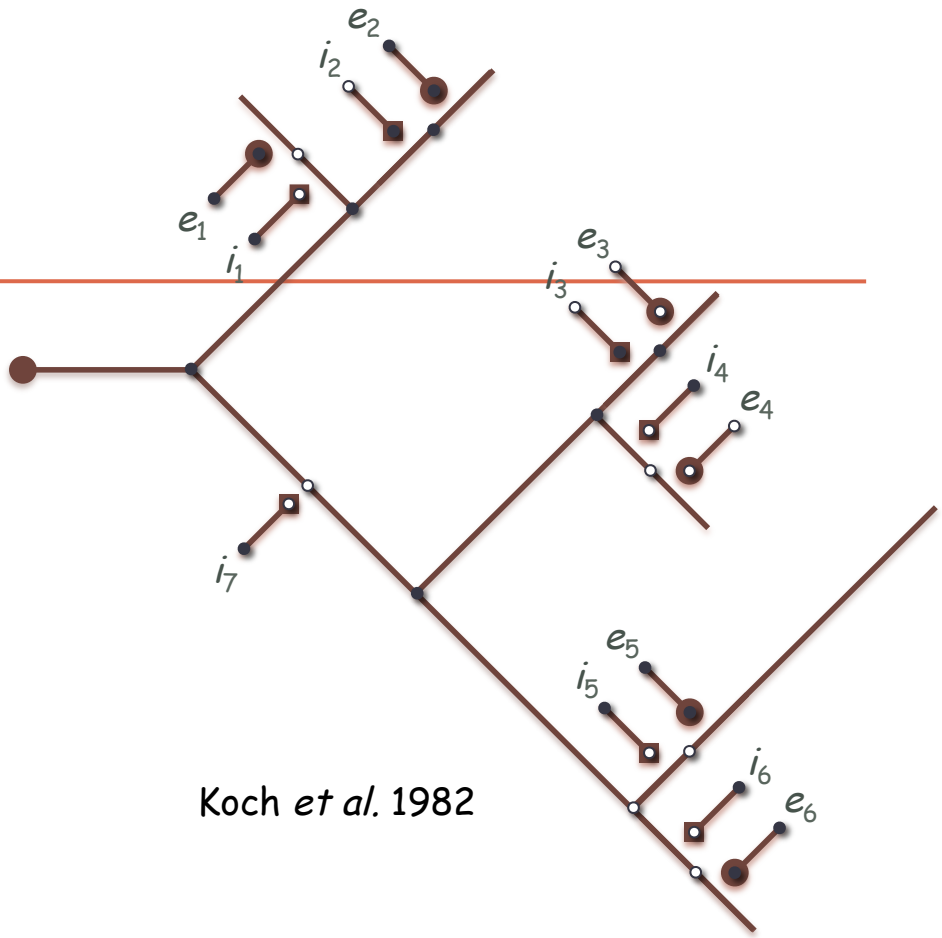


The weighless neuron model

N-tuple sampling machine
Bledsoe and Browning, 1959



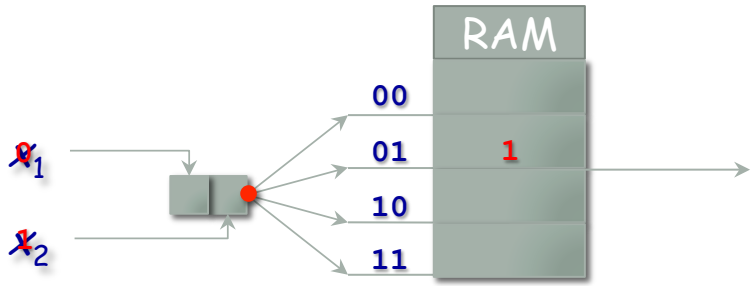
Universal logic circuit
Aleksander, 1966

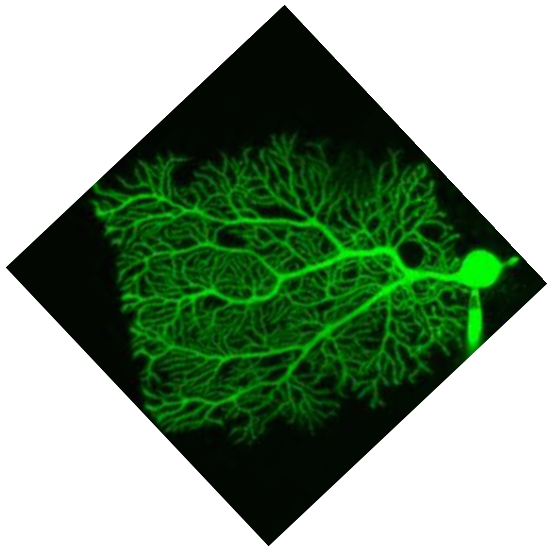


Koch *et al.* 1982

COPPE
UFRJ

The RAM-node



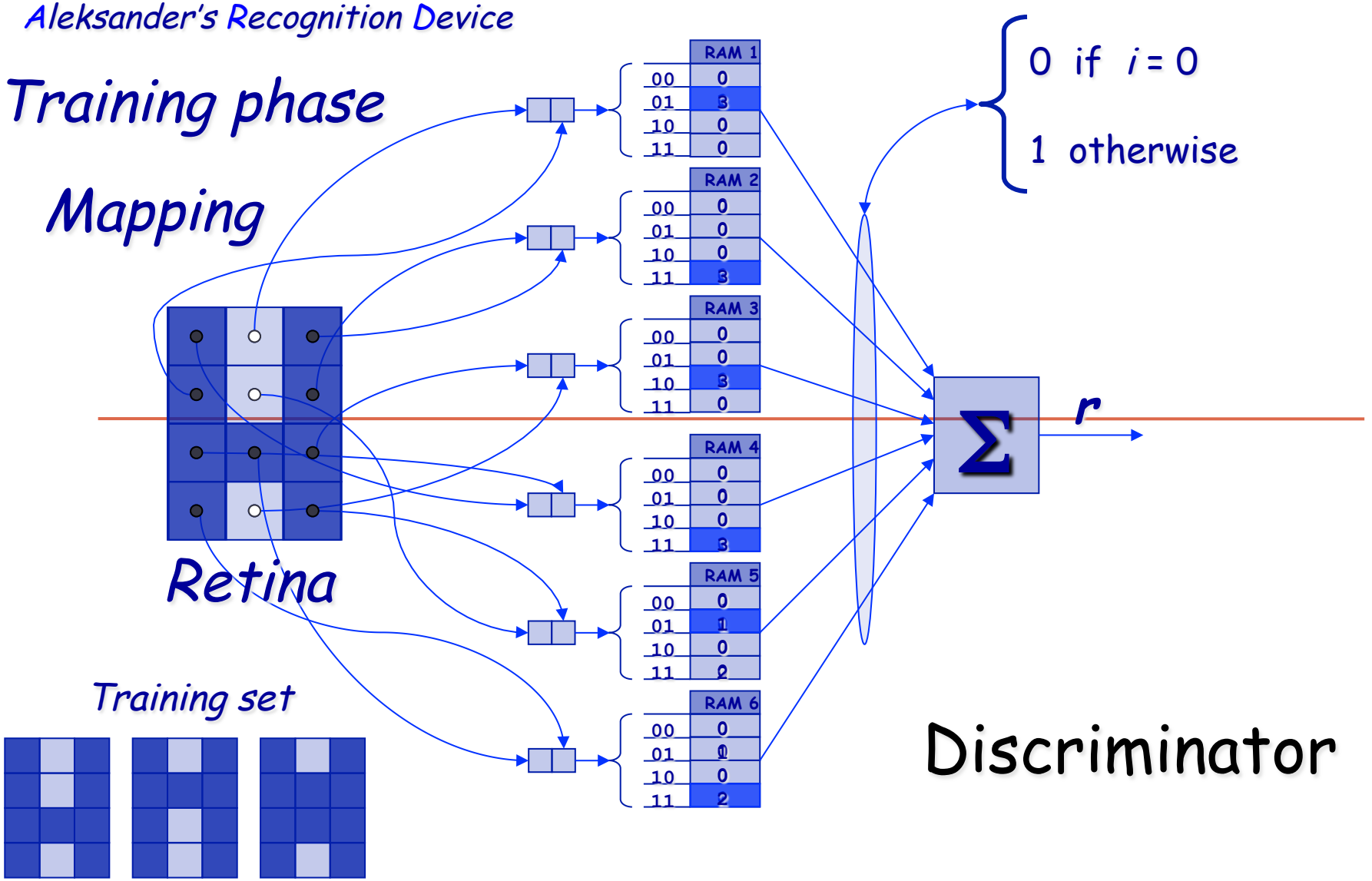


COPPE UFRJ

Wi.S.A.R.D.

Wilkie Stonham and Aleksander's Recognition Device

Modified RAM discriminator

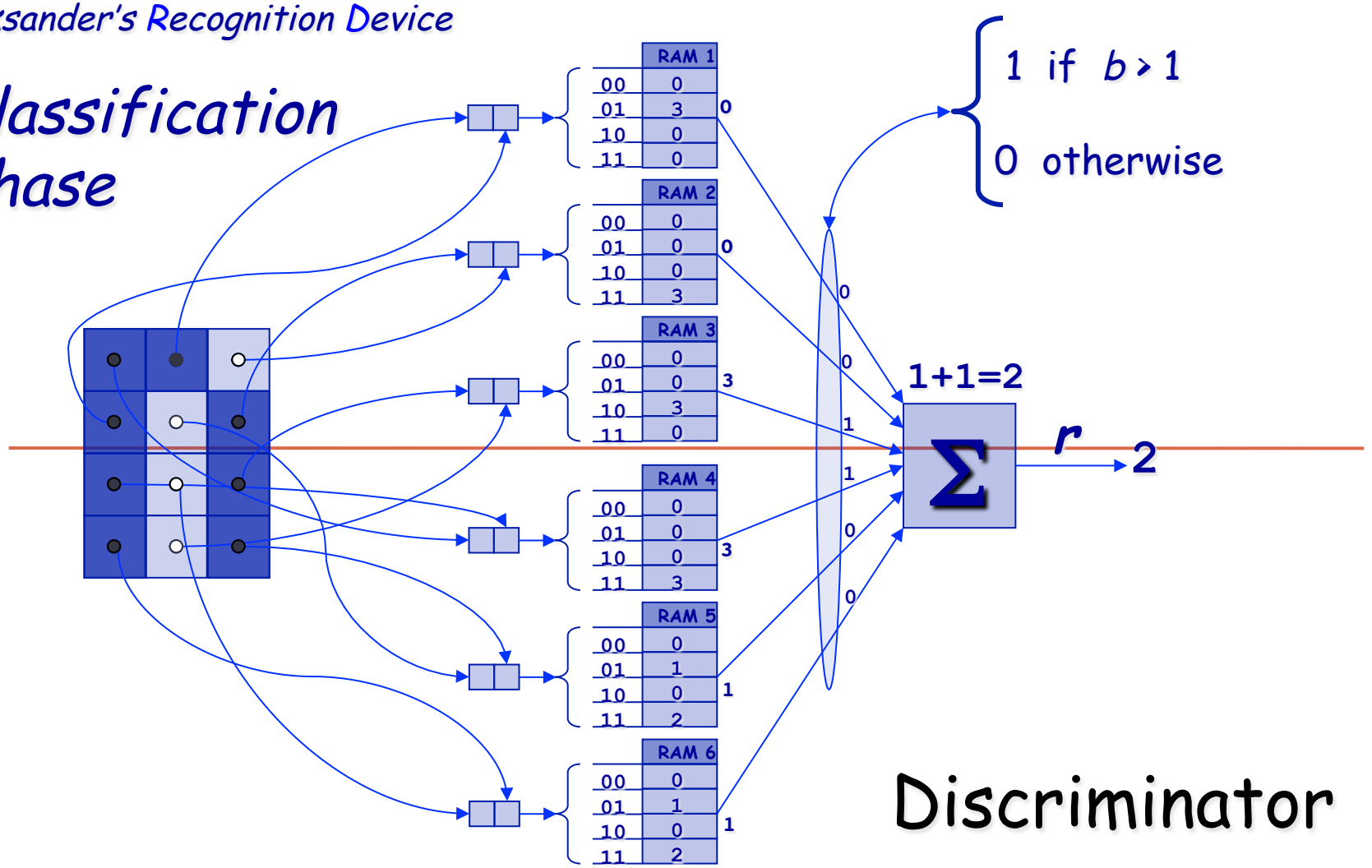


COPPE UFRJ

Wi.S.A.R.D.

Wilkie Stonham and Aleksander's Recognition Device

Modified RAM discriminator



WiSARD in action 1: HIV-1 subtypes – antiretroviral drug resistance

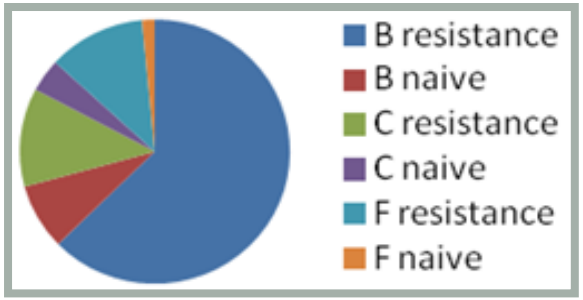
ESANN 2012 proceedings, European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning. Bruges (Belgium), 25-27 April 2012, i6doc.com publ., ISBN 978-2-87419-049-0.
Available from http://www.i6doc.com/en/livre/?GCOI=28001100967420.

Recognition of HIV-1 subtypes and antiretroviral drug resistance using weightless neural networks

Caio R. Souza[1], Flavio F. Nobre[1], Priscila V.M. Lima[2], Robson M. Silva[2], Rodrigo M. Brindeiro[3], Felipe M. G. França[1]

1- COPPE, Universidade Federal do Rio de Janeiro - Brazil
2- DEMAT/ICE, Universidade Federal Rural do Rio de Janeiro – Brazil
3- Laboratory of Molecular Virology, Universidade Federal do Rio de Janeiro - Brazil

Abstract. This work presents an application of an improved version of the WiSARD weightless neural network in the recognition of different mutation types of HIV-1 and in the determination of antiretroviral drugs resistence. The data set used consists of 1205 gene sequence of the HIV-1 protease of subtypes B, C and F from patients under treatment failure. Experiments performed with the *bleaching* technique over the WiSARD model under different data representation strategies have shown promising results, both in terms of accuracy and standard deviation.



- 94% accuracy;
- 1,3% SD;

Next:
- Specific resistance drug recognition;
- Other viral enzimes.

COPPE UFRJ

WiSARD in action 2: early detection of Epilepsy seizures

Early Detection of Epilepsy Seizures based on a Weightless Neural Network*

Kleber de Aguiar[1], Felipe M. G. França[1], Valmir C. Barbosa[1] and César A. D. Teixeira[2]

***Abstract*— This work introduces a new methodology for the early detection of epileptic seizure based on the WiSARD weightless neural network model and a new approach in terms of preprocessing the electroencephalogram (EEG) data. WiSARD has, among other advantages, the capacity of perform the training phase in a very fast way. This speed in training is due to the fact that WiSARD's neurons work like Random Access Memories (RAM) addressed by input patterns. Promising results were obtained in the anticipation of seizure onsets in four representative patients from the European Database on Epilepsy (EPILEPSIAE). The proposed seizure early detection WNN architecture was explored by varying the detection anticipation (δ) in the 2 to 30 seconds interval, and by adopting 2 and 3 seconds as the width of the Sliding Observation Window (SOW) input. While in the most challenging patient (A) one obtained accuracies from 99.57% (δ=2s; SOW=3s) to 72.56% (δ=30s; SOW=2s), patient D seizures could be detected in the 99.77% (δ=2s; SOW=2s) to 99.93% (δ=30s; SOW=3s) accuracy interval.**

TABLE I: Data Recording - Patients Personal Details

Patient (ID-Gender)	Onset Age	Electrodes	Seizure Type SP[1]	CP[2]	SG[3]	UC[4]	Seizure Total
A-Male	13	29	0	8	1	2	11
B-Male	21	29	2	4	0	2	8
C-Female	1	29	6	0	1	1	8
D-Female	23	27	0	4	0	1	5

To achieve this particular goal, i.e., seizure detection, the WiSARD weightless neural network [4] was explored.

The paper is structured as follows: Section 2 describes the dataset used in this work and the methodology developed to performs an early detection of a seizure; Section 3 presents the results obtained; and the conclusion is in the Section 4.

The EEG data used in the experiments made contain only records with clinic seizures annotated. Information about the seizures developed during the data recordings and additional details about the patients data used in this paper are listed in Table I.

*This work was financially supported by CNPq, CAPES and FAPERJ, Brazilian research councils, and the Portuguese national project iCIS (CENTRO-07-0224-FEDER-002003)

[1]Kleber de Aguiar, Felipe Maia Galvão França and Valmir C. Barbosa are with Systems Engineering and Computer Science Program, Federal University of Rio de Janeiro, Caixa Postal 68511, 21941-972, Rio de Janeiro - RJ, Brazil kaguiar@cos.ufrj.br, felipe@cos.ufrj.br, valmir@cos.ufrj.br

[2]César Alexandre Domingues Teixeira is with Centre for Informatics and Systems (CISUC), Faculty of Sciences and Technology, University of Coimbra, Coimbra, Portugal 3030-290 cteixei@dei.uc.pt

[1]Simple Partial
[2]Complex Partial
[3]Secondarily Generalized
[4]Unclassified

978-1-4244-9270-1/15/$31.00 ©2015 IEEE

COPPE UFRJ

WiSARD in action 3:

WIPS: the WiSARD Indoor Positioning System

D. O. Cardoso[1], J. Gama[2], M. De Gregorio[3], F. M. G. França[1], M. Giordano[3] and P. M. V. Lima[4] *

1 - Universidade Federal do Rio de Janeiro, PESC-COPPE
Rio de Janeiro - Brazil

2 - University of Porto, LIAAD-INESC
Porto - Portugal

3 - Istituto di Cibernetica "E. Caianiello" - CNR
Pozzuoli (NA) - Italy

4 - Universidade Federal Rural do Rio de Janeiro, DEMAT-ICE
Seropédica - Brazil

Abstract. In this paper, we present a WiSARD-based system facing the problem of Indoor Positioning (IP) by taking advantage of pervasively available infrastructures (WiFi Access Points – AP). The goal is to develop a system to be used to position users in indoor environments, such as: museums, malls, factories, offshore platforms etc. Based on the fingerprint approach, we show how the proposed weightless neural system provides very good results in terms of performance and positioning resolution. Both the approach to the problem and the system will be presented through two correlated experiments.

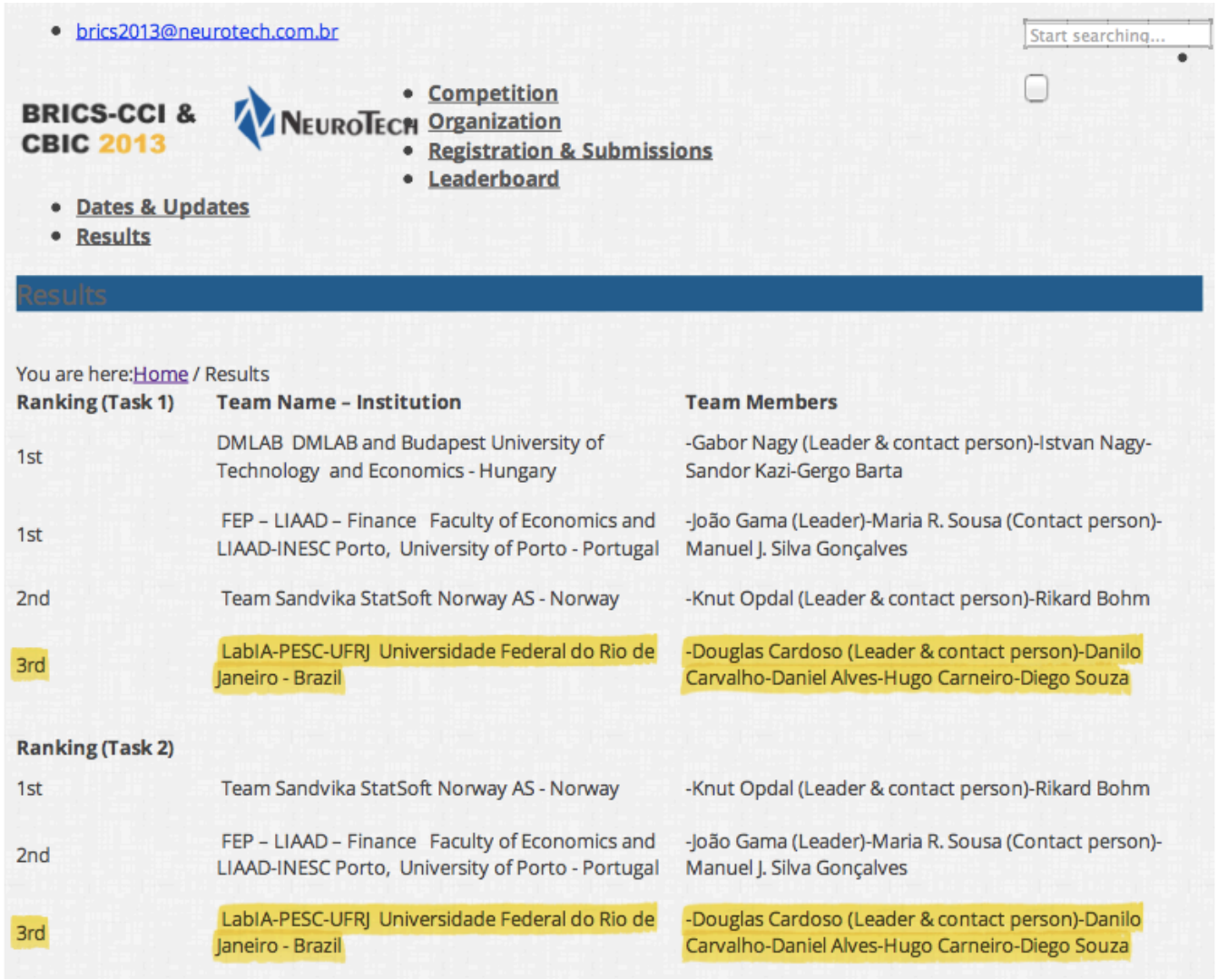
FINEP – Pré-sal,
INOVAX
Parque tecnológico

COPPE UFRJ

WiSARD in action 3:

COPPE UFRJ

WiSARD in action 4:



- brics2013@neurotech.com.br

Start searching...

BRICS-CCI & CBIC 2013

NEUROTECH

- Competition Organization
- Registration & Submissions
- Leaderboard
- Dates & Updates
- Results

Results

You are here:Home / Results

Ranking (Task 1)	Team Name – Institution	Team Members
1st	DMLAB DMLAB and Budapest University of Technology and Economics - Hungary	-Gabor Nagy (Leader & contact person)-Istvan Nagy-Sandor Kazi-Gergo Barta
1st	FEP – LIAAD – Finance Faculty of Economics and LIAAD-INESC Porto, University of Porto - Portugal	-João Gama (Leader)-Maria R. Sousa (Contact person)-Manuel J. Silva Gonçalves
2nd	Team Sandvika StatSoft Norway AS - Norway	-Knut Opdal (Leader & contact person)-Rikard Bohm
3rd	LabIA-PESC-UFRJ Universidade Federal do Rio de Janeiro - Brazil	-Douglas Cardoso (Leader & contact person)-Danilo Carvalho-Daniel Alves-Hugo Carneiro-Diego Souza

Ranking (Task 2)		
1st	Team Sandvika StatSoft Norway AS - Norway	-Knut Opdal (Leader & contact person)-Rikard Bohm
2nd	FEP – LIAAD – Finance Faculty of Economics and LIAAD-INESC Porto, University of Porto - Portugal	-João Gama (Leader)-Maria R. Sousa (Contact person)-Manuel J. Silva Gonçalves
3rd	LabIA-PESC-UFRJ Universidade Federal do Rio de Janeiro - Brazil	-Douglas Cardoso (Leader & contact person)-Danilo Carvalho-Daniel Alves-Hugo Carneiro-Diego Souza

COPPE
UFRJ

WiSARD-based Multi-target tracker

Conclusions, Ongoing and Future Work

ESANN'2009	17th European Symposium On Artificial Neural Networks Advances in Computational Intelligence and Learning Bruges (Belgium), 22-23-24 April 2009

Weightless Neural Systems

14h25 ***Organized by Massimo De Gregorio (Istituto di Cibernetica-CNR, Italy), Priscila M. V. Lima, Felipe M. G. França (Universidade Federal do Rio de Janeiro, Brazil)***

14h25 A brief introduction to Weightless Neural Systems

- Igor Aleksander, Imperial College (United Kingdom)
- Massimo De Gregorio, Istituto di Cibernetica "Eduardo Caianiello" - CNR (Italy)
- Felipe França, Systems Engineering and Computer Science Program, COPPE - Universidade Federal do Rio de Janeiro (Brazil)
- Priscila Lima, Systems Engineering and Computer Science Program, COPPE - Universidade Federal do Rio de Janeiro (Brazil)
- Helen Morton, Brunel University (UK)

Conclusions, Ongoing and Future Work

BRICS7 – Weightless Networks and Stochastic Learning [Session Chair: Felipe França]

WEDNESDAY (9/11) – 09:00-10:00h

Room "E" – "Room Prof. Igor Aleksander" **[Honorary Chair: Igor Aleksander]**

#309 – "Tracking Targets in Sea Surface with the WiSARD Weightless Neural Network", R. S. Moreira, N. F. Ebecken, A. S. Alves

#123 – "A WiSARD–based approach to Cdnet", M. Gregorio, M. Giordano

#101 – "Rock-paper-scissors WiSARD", D. F. P. de Souza, H. C. C. Carneiro, F. M. G. França, P. M. V. Lima

#227 – "Using Survey and Weighted Functions to Generate Node Probability Tables for Bayesian Networks", M. Perkusich, A. Perkusich, H. Almeida

International Supporting Societies

IEEE Computational Intelligence Society | acm Association for Computing Machinery | The International Neural Network Society (INNS)

National Supporting Societies

Brazilian | Russian | Indian | Chinese

Conclusions, Ongoing and Future Work

CBIC7 – (Special session) Weightless Neural Networks [Session Chair: Felipe França]

WEDNESDAY (9/11) – 08:00-09:00h

Room "E" – "Room Prof. Igor Aleksander", Honorary Chair of this Session

#130 – "Classificação por Pixels de Imagens de Sensoriamento Remoto empregando Redes Neurais Sem Peso WiSARD", L. Silva Junior, N. Nedjah, F. França

#329 – "Analysis of Quantum Neural Models", F. M. de Paula Neto, A. J. da Silva, T. B. Ludermir, W. R. de Oliveira

#246 – "Single-shot learning algorithm for quantum weightless neural networks", A. J. da Silva, T. B. Ludermir, W. R. de Oliveira

International Supporting Societies

IEEE Computational Intelligence Society · acm Association for Computing Machinery · The International Neural Network Society (INNS)

National Supporting Societies

Brazilian · Russian · Indian · Chinese

Conclusions, Ongoing and Future Work

ESANN 2014	22nd European Symposium On Artificial Neural Networks, Computational Intelligence and Machine Learning Bruges (Belgium), 23-24-25 April 2014

Friday April 25, 2014

09h00 **Advances on Weightless Neural Systems**
Organized by Massimo De Gregorio, Priscila M.V. Lima, Wilson R. de Oliveira (Italy & Brazil)

09h00 Advances on Weightless Neural Systems

- Massimo De Gregorio, Istituto di Cibernetica (Italy)
- Felipe M. G. França, Universidade Federal do Rio de Janeiro - COPPE/PESC/UFRJ (Brazil)
- Priscila M. V. Lima, Universidade Federal Rural do Rio de Janeiro - Instituto de Ciências Exatas - Departamento de Matemática (Brazil)
- Wilson R. de Oliveira, Universidade Federal Rural de Pernambuco - Departamento de Estatística e Informática (Brazil)

Conclusions, Ongoing and Future Work

European Symposium on Artificial Neural Networks,
Computational Intelligence and Machine Learning

Bruges (Belgium), 22 - 24 April 2015

Wednesday 22 April 2015

09h00 ***Opening***

09h10 **Prototype-based and weightless models**

10h10 A WiSARD-based multi-term memory framework for online tracking of objects

- Daniel Nascimento, Federal University of Rio de Janeiro (Brazil)
- Rafael Carvalho, Federal University of Tocantins (Brazil)
- Felix Mora-Camino, École Nationale de l'Aviation Civile (France)
- Priscila Lima, Federal University of Rio de Janeiro (Brazil)
- Felipe França, Federal University of Rio de Janeiro (Brazil)

10h30 Memory Transfer in DRASiW–like Systems

- De gregorio Massimo, Istituto di Cibernetica (Italy)
- Giordano Maurizio, Istituto di Calcolo e Reti ad Alte Prestazioni - CNR (Italy)

10h50 **Prototype-based and weightless models**
Poster spotlights

COPPE UFRJ

Conclusions, Ongoing and Future Work

Neurocomputing

Special Issue on Weightless Neural Systems

Description:

Mimicking biological neurons by focusing on the excitatory/inhibitory decoding, which is naturally performed by the dendritic trees, is a different and attractive alternative to the integrate-and-fire neuron stylization. In such alternative analogy, neurons can be seen as a set of Random Access Memory (RAM) nodes addressed by Boolean inputs and producing Boolean outputs. The shortening of the semantic gap between

COPPE UFRJ

Conclusions, Ongoing and Future Work

JOURNALS

CARDOSO, D. O. ; CARVALHO, D. S. ; ALVES, D. S. F. ; SOUZA, D. F. P. ; CARNEIRO, H. C. C. ; PEDREIRA, C. E. ; LIMA, P. M. V. ; FRANÇA, F. M. G. . Financial credit analysis via a clustering weightless neural classifier. Neurocomputing (Amsterdam), Accepted.

CARNEIRO, HUGO C.C. ; FRANÇA, FELIPE M.G. ; Lima, Priscila M.V. . Multilingual part-of-speech tagging with weightless neural networks. Neural Networks, v. 66, p. 11-21, 2015.

BARBOZA, R. M. ; COCIORVA, D. ; XU, T. ; BARBOSA, V. C. ; PERALES, J. ; VALENTE, R. H. ; FRANÇA, F. M. G. ; YATES III, J. R. ; CARVALHO, P. C. . Can the false-discovery rate be misleading?. Proteomics (Weinheim. Print), v. 11, p. 1-4, 2011.

GRIECO, B. P. A. ; LIMA, P. M. V. ; DE GREGORIO, M. ; FRANÇA, F. M. G. . Producing pattern examples from mental images?. Neurocomputing (Amsterdam), v. 73, p. 1057-1064, 2010.

LNCS

CARDOSO, D. O. ; DE GREGORIO, M. ; LIMA, P. M. V. ; GAMA, J. ; FRANÇA, F. M. G. . A Weightless Neural Network-Based Approach for Stream Data Clustering. In: Hujun Yin , José A.F. Costa and Guilherme Barreto. (Org.). LNCS (IDEAL 2012). 1ed.Heidelberg: Springer, 2012, v. 7435, p. 328-335.

COPPE UFRJ

Conclusions, Ongoing and Future Work

PROCEEDINGS (1/5)

NASCIMENTO, D. N. ; CARVALHO, R. L. ; MORA-CAMINO, F. ; LIMA, P. M. V. ; FRANÇA, F. M. G. . A WiSARD-based multi-term memory framework for online tracking of objects. In: European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2015, Bruges. Proc. of ESANN 2014. Louvain-la-Neuve: i6doc.com, 2015. p. 19-24.

SOUZA, DIEGO F.P. DE ; FRANCA, FELIPE M.G. ; Lima, Priscila M.V. . Real-Time Music Tracking Based on a Weightless Neural Network. In: 2015 Ninth International Conference on Complex, Intelligent, and Software Intensive Systems (CISIS), 2015, Santa Catarina. 2015 Ninth International Conference on Complex, Intelligent, and Software Intensive Systems. p. 64-69.

DE AGUIAR, KLEBER ; FRANCA, FELIPE M. G. ; BARBOSA, VALMIR C. ; TEIXEIRA, CESAR A. D. . Early detection of epilepsy seizures based on a weightless neural network. In: 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2015, Milan. 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2015. p. 4470.

CARDOSO, DOUGLAS O. ; FRANCA, FELIPE ; GAMA, JOAO . A bounded neural network for open set recognition. In: 2015 International Joint Conference on Neural Networks (IJCNN), 2015, Killarney. 2015 International Joint Conference on Neural Networks (IJCNN), 2015. p. 1.

COPPE UFRJ

Conclusions, Ongoing and Future Work

PROCEEDINGS (2/5)

FRANÇA, F. M. G. ; DEGREGORIO, M. ; LIMA, P. M. V. ; OLIVEIRA JR, W. R. . Advances in Weightless Neural Systems. In: European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2014, Bruges. Proc. of ESANN 2014. Brussels: i6doc.com, 2014. p. 497-504.

CARDOSO, D. O. ; CARVALHO, D. S. ; ALVES, D. S. F. ; SOUZA, D. F. P. ; CARNEIRO, H. C. C. ; PEREIRA, C. E. ; LIMA, P. M. V. ; FRANÇA, F. M. G. . Credit Analysis with a clustering RAM-based neural classifier. In: European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2014, Bruges. Proc. of ESANN 2014. Brussels: i6doc.com, 2014. p. 517-522.

COUTINHO, P. V. S. ; CARNEIRO, H. C. C. ; CARVALHO, D. S. ; FRANÇA, FELIPE M.G. . Extracting rules from DRASiW's 'mental images'. In: European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2014, Bruges. Proc. of ESANN 2014. Brussels: i6doc.com, 2014. p. 529-534.

CARVALHO, R. L. ; CARVALHO, D. S. ; MORA-CAMINO, F. ; LIMA, P. M. V. ; FRANÇA, F. M. G. . Online tracking of multiple objects using WiSARD. In: European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2014, Bruges. Proc. of ESANN 2014. Brussels: i6doc.com, 2014. p. 541-546.

CARVALHO, DANILO SILVA DE ; FRANCA, FELIPE MAIA GALVAO ; LIMA, PRISCILA MACHADO VIEIRA . Extracting Semantic Information from Patent Claims Using Phrasal Structure Annotations. In: 2014 Brazilian Conference on Intelligent Systems (BRACIS), 2014, Sao Paulo. 2014 Brazilian Conference on Intelligent Systems. p. 31-36.

COPPE UFRJ

Conclusions, Ongoing and Future Work

PROCEEDINGS (3/5)

CARVALHO, D. S. ; CARNEIRO, H. C. C. ; FRANÇA, F. M. G. ; LIMA, P. M. V. . B-bleaching: Agile Overtraining Avoidance in the WiSARD Weightless Neural Classifier. In: European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2013, Bruges. Proc. of ESANN 2013. Brussels: 6doc.com, 2013. v. 1. p. 515-520.

CARDOSO, D. O. ; GAMA, J. ; DEGREGORIO, M. ; FRANÇA, F. M. G. ; GIORDANO, M. ; LIMA, P. M. V. . WIPS: the WiSARD Indoor Positioning System. In: European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2013, Bruges. Proc. of ESANN 2013. Brussels: 6doc.com, 2013. v. 1. p. 521-526.

MOREIRA, R. S. ; EBECKEN, N. F. ; ALVES, A. S. ; FRANÇA, F. M. G. . Tracking Targets in Sea Surface with the WiSARD Weightless Neural Network. In: BRICS-CCI, 2013, Ipojuca, PE. Proc. of BRICS-CCI & CBIC 2013, 2013. v. 1. p. 1-6.

SOUZA, D. F. P. ; CARNEIRO, H. C. C. ; FRANÇA, F. M. G. ; LIMA, P. M. V. . Rock-paper-scissors WiSARD. In: BRICS-CCI, 2013, Ipojuca, PE. Proc. of BRICS-CCI & CBIC 2013, 2013. v. 1. p. 1-6.

ALVES, D. S. F. ; CARDOSO, D. O. ; CARNEIRO, H. C. C. ; FRANÇA, F. M. G. ; LIMA, P. M. V. . An empirical study of the influence of data structures on the performance of VG-RAM classifiers. In: BRICS-CCI, 2013, Ipojuca, PE. Proc. of BRICS-CCI & CBIC 2013, 2013. v. 1. p. 1-6.

COPPE UFRJ

Conclusions, Ongoing and Future Work

PROCEEDINGS (4/5)

SOUZA, C. R. ; NOBRE, F. F. ; LIMA, P. M. V. ; SILVA, R. M. ; BRINDEIRO, R. M. ; FRANÇA, F. M. G. . Recognition of HIV-1 subtypes and antiretroviral drug resistance using weightless neural networks. In: European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2012, Bruges. Proc. of ESANN 2012. Brussels: 6doc.com, 2012. v. 1. p. 429-434.

PINTO, F. A. N. C. ; PACHECO, W. S. ; SIQUEIRA, R. S. ; FRANÇA, F. M. G. . Comparison between pattern recognition schemes from noise mappings. In: 19th International Congress on Sound and Vibration, 2012, Vilnius. Proc. of ICSV 2012, 2012. v. 4. p. 2745-2752.

CARDOSO, D. O. ; LIMA, P. M. V. ; DE GREGORIO, M. ; GAMA, J. ; FRANÇA, F. M. G. . Clustering data streams with weightless neural networks. In: 19th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, 2011, Bruges. Proc. of ESANN 2011. Louvain-la-Neuve: i6doc, 2011. v. 1. p. 201-206.

CARNEIRO, H. C. C. ; FRANÇA, F. M. G. ; LIMA, P. M. V. . WANN-TAGGER: A Weightless Artificial Neural Network Tagger for the Portuguese Language. In: International Conference on Neural Computation, 2010, Valencia. Proc. of the 2nd International Joint Conference on Computational Intelligence. Lisboa: SciTePress Science and Technology Publications, 2010. p. 330-335.

COPPE UFRJ

Conclusions, Ongoing and Future Work

PROCEEDINGS (5/5)

FRANCA, H. L. ; SILVA, J. C. P. ; DE GREGORIO, M. ; LENGERKE, O. ; DUTRA, M. S. ; FRANÇA, F. M. G. . Movement Persuit Control of an Offshore Automated Platform via a RAM-based Neural Network. In: 11th. Int. Conf. Control, Automation, Robotics and Vision, 2010, Singapore. Proc. of ICARCV 2010. Piscataway: IEEE Press, 2010. v. 1. p. 2437-2441.

ALEKSANDER, I. ; DE GREGORIO, M. ; FRANÇA, F. M. G. ; LIMA, P. M. V. ; MORTON, H. . A Brief introduction to Weightless Neural Systems. In: 17th European Symposium on Artificial Neural Networks, 2009, Bruges. Proc. of ESANN 2009. Evere, Belgium: d-side, 2009. p. 299-305.

GRIECO, B. P. A. ; LIMA, P. M. V. ; DE GREGORIO, M. ; FRANÇA, F. M. G. . Extracting fuzzy rules from "mental" images generated by modified WiSARD perceptrons. In: 17th European Symposium on Artificial Neural Networks, 2009, Bruges. Proc. of ESANN 2009. Evere, Belgium: d-side, 2009. p. 313-318.

COPPE UFRJ

http://labia.cos.ufrj.br/publicacoes/artigos/weightless-hierarchy-memory-tracker

Thank you, Obrigado!

felipe@ieee.org

COPPE UFRJ

Universidade Federal do Rio de Janeiro