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Engineering Applications of Neural Networks

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Preface

It has been more than 60 years since John McCarthy introduced the term AI (Artificial Intelligence) to the scientific community. Since then, for the vast majority of the population, AI sounds more like a mythical future prediction not very close to reality. Common people use AI in their daily lives but they do not actually realize it. For example, cars make extensive use of Artificial Narrow Intelligence (ANI) to figure out when the anti-lock brakes should be used, or to control the fuel injection systems. The same use of ANI applies in our smart cell phones or in the Google search engine.

Artificial Neural Networks (ANNs) are a very important chapter of AI and more specifically a branch of Computational Intelligence and Soft Computing. Their applications are applied in diverse scientific areas, such as medical science, finance and management, environmental science, control systems, and telecommunications. For example ANNs are used in flight bookings and dynamic allocation of seats, in credit evaluation, in mortgage screening, pattern recognition, and image and video analysis. Even NASA used ANNs to develop the IFCS (Intelligent Flight Control System).

The Engineering Applications of Neural Networks (EANN) conference was established in Otaniemi, Finland in 1995, exactly 20 years ago. Since then it has become a well-established event with a very long and successful history. In the years that followed, it has achieved a continuous and dynamic presence as a major European scientific event with participants from all over the globe. An important milestone was the year 2009, when its guidance by a Steering Committee of the INNS (EANN Special Interest Group) was initiated. Thus, from that moment, the conference has been continuously supported technically by the International Neural Network Society (INNS). This year, it was scientifically and administratively supported by the Aristotle University of Thessaloniki and the Democritus University of Thrace, Greece. The event was held during September 25–28, 2015, in the "Amilia Mare" Resort and Conference Centre on Rhodes Island, Greece.

The Organizing Committee was delighted by the overwhelming response to the call for papers. In total, 84 original research papers were submitted to the EANN 2015 conference. The diverse nature of papers submitted demonstrates the vitality of neural computing and related soft computing approaches and proves the very wide range of ANN applications as well.

All papers passed through a review process by at least two independent academic referees. Where needed a third referee was consulted to resolve any conflicts. Overall 43 % of the submitted manuscripts (36 in total) were accepted for inclusion in this volume of the Communications in Computer and Information Science (CCIS) series by Springer. The accepted papers of the 16^{th} EANN conference are related to the following thematic topics:

- Industrial Applications of ANN
- Bioinformatics
- Intelligent Medical Modelling

- Intelligent Modelling in Life-Earth Sciences
- Learning Algorithms
- Smart Telecommunications Modelling
- Fuzzy Modelling
- Robotics and Control
- Smart Cameras
- Pattern Recognition
- Emotion Recognition
- Classification
- Intelligent Financial Modelling
- Echo State Networks
- ANN Modelling

The authors of accepted papers came from 21 different countries from all over Europe (e.g., Austria, the Czech Republic, Finland, Germany, Greece, Hungary, Italy, The Netherlands, Poland, Portugal, Russia, Spain, and the UK), the Americas (e.g., Brazil, Chile, and the USA), Asia (e.g., Israel, India, and Iran), Africa (e.g., Algeria) and Oceania (New Zealand).

Three keynote speakers were invited to give lectures in timely aspects of AI and ANN.

1. Prof. Nikola Kasabov of the School of Computing and Mathematical Sciences at Auckland University of Technology, Australia, delivered a talk on: "Neuromorphic Predictive Systems Based on Deep Learning."
2. Prof. Barbara Hammer of Bielefeld University, Germany, delivered a talk on "Autonomous Model Selection for Prototype Based Architectures," and
3. Prof. Paul Verschure of the Universitat Pompeu Fabra, Barcelona, Spain, delivered a talk on "Engineering Biologically and Psychologically Grounded Living Machines: The Distributed Adaptive Control Theory of Mind, Brain and Behaviour."

In addition, two highly interesting tutorials were given within the framework of EANN 2015. The first one was delivered by Assistant Prof. Giacomo Boracchi from the Department of Electronics and Informatics, Politecnico di Milano, Italy. It was entitled "Learning under Concept Drift: Methodologies and Applications." The second tutorial was delivered by Prof. Vera Kurkova from the Institute of Computer Science, Czech Academy of Sciences, Czech Republic. The subject was "Strength and Limitations of Shallow Networks." We wish to express our sincere thanks to both distinguished scientists.

Finally, three workshops on timely AI subjects were organized successfully and collocated with EANN 2015:

1. The 4th Mining Humanistic Data Workshop (MHDW), supported by the Ionian University and the University of Patras. We wish to express our gratitude to Profs. Christos Makris and Katia Linda Kermanidis, and Dr. Ioannis Karydis for their common effort towards the organization of the 4^{th} MHDW workshop.
2. The 5th Workshop on Artificial Intelligence Applications in Biomedicine (AIAB), supported by the Frederick University Cyprus, University of Piraeus Greece, and

the Democritus University of Thrace, Greece. We are grateful to Profs. Harris Papadopoulos, Efthyvoulos Kyriacou, Ilias Maglogiannis, and George Anastassopoulos for their hard work in managing the 5th AIAB workshop.

3. The 2nd Innovative European Policies and Applied Measures for Developing Smart Cities (IPMSC) Workshop, supported by the Hellenic Telecommunications Organization (OTE). The IPMSC was driven by the hard work of Drs. Ioannis P. Chochliouros and Ioannis M. Stephanakis (OTE, Greece).

We hope that these proceedings will help researchers worldwide to understand and to be aware of the latest developments in ANNs. We do believe that they will be of major interest to scientists over the globe and that they will stimulate further research in the domain of Artificial Neural Networks and AI in general.

September 2015

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Invited Talks

Neuromorphic Predictive Systems Based on Deep Learning

Nikola Kasabov

School of Computing and Mathematical Sciences,
Auckland University of Technology, Auckland, Australia

Abstract. The current development of the third generation of artificial neural networks - the spiking neural networks (SNN) [1, 5, 9] along with the technological development of highly parallel neuromorphic hardware systems of millions of artificial spiking neurons as processing elements [2, 3], makes it possible to model big and fast data in a fast on-line manner, enabling large-scale problem solving across domain areas including building better predictive systems. The latter topic is covered in this talk. The talk first presents some principles of deep learning inspired by the human brain, such as automated feature selection, ‘chain fire’, polychronisation. These principles are implemented in a recent evolving SNN (eSNN) architecture called NeuCube [4] and its software development system that is made available from: www.kedri.aut.ac.nz/neucube/. These principles allow for an eSNN system to predict events and outcomes, so that once the eSNN is trained on whole spatio-temporal patterns, it can be made to spike early, when only a part of a new pattern is presented as input data. The talk presents a methodology for the design and implementation of NeuCube-based eSNN systems for deep learning and early and accurate outcome prediction from large-scale spatio-/spectro temporal data, referred here as spatio-temporal data machines (STDM). A STDM has modules for: preliminary data analysis, data encoding, pattern learning, classification, regression, prediction and knowledge discovery. This is illustrated on early event prediction tasks using benchmark large spatio/spectro-temporal data with different spatial/temporal characteristics, such as: EEG data for brain computer interfaces; personalised and climate date for stroke occurrence prediction and for the prediction of ecological and seismic events [6–8]. The talk discusses implementation on highly parallel neuromorphic hardware platforms such as the Manchester SpiNNaker [2] and the ETH Zurich chip [3, 10]. The STDM are not only significantly more accurate and faster than traditional machine learning methods and systems, but they lead to a significantly better understanding of the data and the processes that generated it.

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Bio. Professor Nikola Kasabov is Fellow of IEEE, Fellow of the Royal Society of New Zealand and DVF of the Royal Academy of Engineering, UK. He is the Director of the Knowledge Engineering and Discovery Research Institute (KEDRI), Auckland. He holds a Chair of Knowledge Engineering at the School of Computing and Mathematical Sciences at Auckland University of Technology. Kasabov is a Past President and Governors Board member of the International Neural Network Society (INNS) and also of the Asia Pacific Neural Network Assembly (APNNA). He is a member of several technical committees of IEEE Computational Intelligence Society and a Distinguished Lecturer of the IEEE CIS (2011–2013). He is a Co-Editor-in-Chief of the Springer journal Evolving Systems and has served as Associate Editor of Neural Networks, IEEE TrNN, IEEE TrFS, Information Science and other journals. Kasabov holds MSc and PhD from the TU Sofia, Bulgaria. His main research interests are in the areas of neural networks, intelligent information systems, soft computing, bioinformatics, neuroinformatics. He has published more than 560 publications that include 15 books, 180 journal papers, 90 book chapters, 30 patents and numerous conference papers. He has extensive academic experience at various academic and research organisations in Europe and Asia, including: TU Sofia, University of Essex, University of Trento, University of Otago, Guest professor at the Shanghai Jiao Tong University, Guest Professor at ETH/University of Zurich, DAA Professor TU Kaiserlautern. Prof. Kasabov has received the APNNA 'Outstanding Achievements Award', the INNS Gabor Award for 'Outstanding contributions to engineering applications of neural networks', the EU Marie Curie Fellowship, the Bayer Science Innovation Award, the APNNA Excellent Service Award, the RSNZ Science and Technology Medal, and others. He has supervised to completion 40 PhD students. More information of Prof. Kasabov can be found on the KEDRI web site: http://www.kedri.aut.ac.nz.

Autonomous Model Selection for Prototype Based Architectures

Barbara Hammer

Bielefeld University, Bielefeld, Germany

Abstract. Prototype-based learning techniques enjoy a wide popularity due to their intuitive training techniques and model interpretability. Applications include biomedical data analysis, image classification, or fault detection in technical systems. One striking property of such models consists in the fact that they represent data in terms of typical representatives; this property allows an efficient extension of the techniques to life-long learning and model adaptation for streaming data. Within the talk, we will mainly focus on modern variants of so-called learning vector quantization (LVQ) due to their strong learning theoretical background and exact mathematical derivative from explicit cost functions. We will focus on three aspects which are of particular interest if these models are used as autonomous learning models: 1) metric learning in prototype based models, 2) incremental learning with adaptive model complexity, and 3) optimum reject options. Metric learning autonomously adjusts the used metric, usually the Euclidean one, towards a richer and more problem-adjusted representation of the data. Metric learning does not only greatly enhance the model performance, but it usually also increases model interpretability, a very important property e.g. in biomedical data applications. We will discuss recent results which investigate metric learning mechanisms with a focus on their uniqueness, and we will present efficient schemes which account for a regularization of this process in particular for high dimensional data. Further, we will show that metric learning in LVQ techniques can be extended towards nonvectorial data such as sequences. Incremental learning and the possibility to reject classification are tightly interwoven aspects. These properties enable to autonomously adjust model complexity, and they enhance the system with the capability to judge its limitations in classification accuracy. We will present recent work which investigates different measurements which allow the quantification of the model insecurity, including the notion of conformal measures as one approach with very clear statistical background. Based on such measures, we will present incremental models with self-adjusted mode complexity, on the one hand, and an efficient strategy for an optimum combination of rejects in a mathematically precise sense, on the other hand.

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Bio. Barbara Hammer received her Ph.D. in Computer Science in 1995 and her venia legendi in Computer Science in 2003, both from the University of Osnabrueck, Germany. From 2000–2004, she was chair of the junior research group Learning with Neural Methods on Structured Data' at University of Osnabrueck before accepting an offer as professor for Theoretical Computer Science at Clausthal University of Technology, Germany, in 2004. Since 2010, she is holding a professorship for Theoretical Computer Science for Cognitive Systems at the CITEC cluster of excellence at Bielefeld University, Germany. Several research stays have taken her to Italy, U.K., India, France, the Netherlands, and the U.S.A. Her areas of expertise include hybrid systems, self-organizing maps, clustering, and recurrent networks as well as applications in bioinformatics, industrial process monitoring, or cognitive science. She has been chairing the IEEE CIS Technical Committee on Data Mining in 2013 and 2014, and she is chair of the Fachgruppe Neural Networks of the GI and vice-chair of the GNNS. She has published more than 200 contributions to international conferences / journals, and she is coauthor/editor of four books.

Engineering Biologically and Psychologically Grounded Living Machines: The Distributed Adaptive Control Theory of Mind, Brain and Behaviour

Paul Verschure

Catalan Institute of Advanced Research (ICREA),
Technology Department, Universitat Pompeu Fabra, Barcelona, Spain

Abstract. Our society is facing a number of fundamental challenges in a range of domains that will require a new class of machines. I will call these Living Machines and will describe how their engineering will depend on extracting fundamental design principles from nature. In particular I will emphasize the emergence of a new class of machines that are based on our advancing understanding of mind and brain. The argument that this can lead to a new form of engineering is based on the Distributed Adaptive Control (DAC) that has been applied in a range of domains including robotics, the clinic and in education. DAC is based on the assumption that the brain evolved to maintain a dynamic equilibrium between an organism and its environment through action. The fundamental question that such a brain has to solve in order to deal with the how of action in a physical world is: why (motivation), what (objects), where (space), when (time) or the H4W problem. Post the Cambrian explosion of about 560M years ago, a last factor became of great importance for survival: the who of other agents. I propose that H5W defines the top-level objectives of the brain and will argue that brain and body evolved to provide specific solutions to it by relying on a layered control architecture that is captured in DAC. I will show how DAC addresses H5W through interactions across multiple layers of neuronal organization, suggesting a very specific structuring of the brain, which can be captured in robot control architectures. In explaining how the function of the brain is realized I will show how the DAC theory provides for very specific predictions that have been validated at the level of behaviour and the neuronal substrate. Subsequently I will show how the DAC theory has given rise to a qualitative new class of clinical interventions for the rehabilitation of deficits following stroke illustrating the notion of deductive medicine. These examples will show that robot based models of mind and brain do not only advance our understanding of ourselves and other animals but can also lead to novel technical solutions to complex applied problems.

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Bio. Paul Verschure is an ICREA Research Professor in the Department of Information and Communication Technologies at Universitat Pompeu Fabra (UPF). He received both his Master and Ph.D. in psychology. He has pursued his research at different leading institutes: the Neurosciences Institute and the Salk Institute (both in San Diego), the University of Amsterdam, University of Zurich and the Swiss Federal Institute of Technology-ETH and currently with ICREA and UPF. Editorial Board of Acta Neurobiologiae Experimentalis (Polish Neuroscience Society). Conference Chair for the Barcelona Cognition, Brain & Technology Summer School 2008, 2009, 2010,2011, 2012, 2013 and 2014. Advisory Board Member for: Ernst Strüngmann Forum 2011 and the 2010 & 2011 CCL Linnaeus Environment (Cognition, Communication and Learning). Dr. Verschure has published over 250 peer-reviewed papers in leading scientific journals including Nature, Science, Neuron, PLoS Biology and PLoS Computational Science, Proceedings of the National Academy of Sciences USA, the Royal Society London and Public Library of Science. He holds 2 patents. Relevant technology projects include Ada: Intelligent Space at Expo'02(Switzerland). SPECS is the 1 of only 6 labs worldwide to receive the European humanoid platform iCub in the first iCub competitive call.

Tutorials

Learning Under Concept Drift: Methodologies and Applications

Giacomo Boracchi

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Abstract. Most machine learning techniques assume that the process generating the data is stationary. This guarantees that the model learned during the initial training phase remains valid during the subsequent operation. Unfortunately, stationarity is often an oversimplifying assumption because real-world processes typically change overtime. In the classification literature, changes in the data-generating process are referred to as concept drift.

Learning under concept-drift is a challenging research topic. In fact, in addition to the online-learning issues, the learner has to deal with possible changes, which would make it obsolete and unfit. Given the fact that changes are often unpredictable, as they might occur at any time and shift the data-generating process to an unforeseen state, the learner has to either undergo continuous adaptation to match the recent operating conditions (passive approach) or to steadily monitor the data stream to detect changes and, eventually, react (active approaches). In the last few years, there has been a flourishing of algorithms designed for learning under concept drift, also given the large number of applications where these techniques can be employed.

The tutorial introduces the main issues of learning under concept drift, the active and passive approaches as two extreme adaptation strategies, and few relevant applications such as those related to fraud-detection or those meant for detecting anomalies/changes in streams of signals and images

Strength and Limitations of Shallow Networks

Vera Kurkova

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Abstract. Although originally biologically inspired neural networks were introduced as multilayer computational models, later shallow (one-hidden-layer) architectures became dominant in applications. Recently, interest in architectures with several hidden layers was renewed due to successes of deep convolutional networks. These experimental results motivated theoretical research aiming to characterize tasks which can be computed more efficiently by deep networks than by shallow ones. This tutorial will review recent developments regarding theoretical analysis of strength and limitations of shallow networks. The tutorial will focus on the following topics:

- Universality and tractability of representations of multivariable mappings by shallow networks.
- Trade-off between maximal generalization capability and model complexity.
- Limitations of computation of highly-varying functions by shallow networks.
- Probability distributions of functions which cannot be tractably represented by shallow networks.
- Examples of representations of high-dimensional classification tasks by one and two-hidden-layer networks.

Attendees will learn about consequences of these theoretical results for the methodology of choosing a neural network architecture and about open problems related to deep and shallow architectures.

Contents