Current Trends in Machine Learning for Signal Processing (MLSP)

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First, a very brief history...

- Started existence as the Technical Committee on *Neural Networks for Signal Processing* (NNSP) in 1990
- First NNSP Workshop September 1991, in Princeton, NJ
- First TC Chair, Fred B. H. Juang
- Yearly workshops since 1991
Yearly workshops since 1991

Workshops on Neural Network for Signal Processing

- NNSP 1992, August 31–September 2, Hotel Marienlyst, Helsingor, Denmark
- NNSP 1993, September 6–9, Linthicum, Maryland, USA
- NNSP 1994, September 6–8, Proto Hydra Resort Hotel, Ermioni, Greece
- NNSP 1995, August 31–September 2, Royal Sonesta Hotel, Cambridge, Boston, USA
- NNSP 1996, September 4–6, Keihanna, Seika, Kyoto, Japan
- NNSP 1997, September 24–26, Amelia Island Plantation, Florida, USA
- NNSP 1998, August 31–September 2, Newton Institute, Cambridge, England
- NNSP 1999, August 23–25, Madison, Wisconsin, USA
- NNSP 2000, December 11–13, Sydney, Australia
- NNSP 2001, September 10–12, Falmouth, USA
- NNSP 2002, September 4–6, 2002, Martigny, Valais, Switzerland
- NNSP 2003, September 17–19, 2003, Toulouse, France

Workshops on Machine Learning for Signal Processing

- MLSP 2004, September 29–October 1, 2004, São Luis, Brazil
- MLSP 2005, September 28–30 2005, Mystic, USA
- MLSP 2006, September 6–8, 2006, Maynooth, Ireland
- MLSP 2007, August 27–29, 2007, Thessaloniki, Greece
- MLSP 2008, October 16–19, 2008, Cancún, Mexico
- MLSP 2009, September 2–4, 2009, Grenoble, France
- MLSP 2010, August 29–September 1, 2010, Kittila, Finland
- MLSP 2011, September 18–21, 2011, Beijing, China

Tülay Adalı
MLSP TC
“Neural Network for Signal Processing” was deemed to be too narrow a scope by many.

Working with the IEEE SPS President at the time, Fred Mintzer, the TC approved the name: Machine Learning for Signal Processing which became the TC’s new name after approval by the BoG.
The bridge between *machine learning* and *signal processing*

*Learning* is the key aspect

*Signal processing* defines the main applications of interest and the constraints

Attractive solutions for traditional signal processing applications such as pattern recognition, speech, audio, and video processing

Primary candidates for emerging applications such as BCI, multimodal data fusion and processing, behavior and emotion recognition, and learning in environments such as social networks
Applications of machine learning
Bayesian learning; Bayesian signal processing
Cognitive information processing
Graphical and kernel methods
Independent component analysis
Information-theoretic learning
Learning theory and algorithms
Neural network learning
Pattern recognition and classification
Bounds on performance
Sequential learning; sequential decision methods
Source separation
Areas of activity, emerging trends

Methods
- Sparsity-aware learning
- Learning in kernel spaces
- Semi-supervised learning
- Distributed learning
- Subspace and manifold learning
- Semi-blind data analysis, learning

Besides learning, *integration* of approaches has been a key emphasis, making MLSP a natural home for
- brain-computer interface
- behavior and emotion recognition
- multimodal data fusion and processing
- multiple/joint data analysis
- learning in environments such as social networks
Cognitive information processing represents a major paradigm shift in learning

A dynamic system is called *cognitive* if it exhibits all four cognitive properties:

- **Perception-action cycle**, which produces information gain about the environment, obtained from one cycle to the next
- **Memory**, which predicts the consequences of action on/in the environment
- **Attention**, which is responsible for the allocation of available resources
- Finally, **intelligence** provides the basis for decision-making whereby intelligence choices are made in the face of environmental uncertainties
Trends in Machine Learning for Signal Processing

Kostas Diamantaras
TEI of Thessaloniki, Greece
Data collected from paper titles appearing in ICASSPs (MLSP track) and MLSP workshops between 2007-2011
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NEURAL, ANN, RBF, MLP, ... — BRAIN COMPUTER INTERFACES

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3/6/2011  Diamantaras, ICASSP 2011, Prague, Czechia  3
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Cognitive information processing
- an emerging trend for MLSP

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Why is it important? VISION

What should we do? MISSION
The legacy

Allan Touring
Theory of computing, 1940’es

Norbert Wiener
Cybernetics 1948

processing  adaption  understanding  cognition

information and data

people
Vision

Cognition refers to the representations and processes involved in thinking and decision making. Cognitive information processing integrate information processing in brains and computers for collaborative problem solving in open-ended environments.

The vision is to design and implement profound cognitive information processing systems for augmented human cognition in real-life environments.

Disentanglement of confusing, ambiguous, conflicting, and vast amounts of multimodal, multi-level data and information.
Visnevski / Castillo-Effen tiered approach

How much is needed to qualify the system as being cognitive?

A tiered approach: from low to high-level capabilities

- Robustness
- Adaptivity
- Efficiency
- Natural interaction
- Emergent properties

It takes cross-disciplinary effort to create a cognitive system

INFO
Engineering and natural sciences

COG
Cognitive psychology, social sciences, linguistics

CIP

BIO
Neuro and life sciences

Revitalizing old visions through cognitive information processing systems by means of enabling technologies

**Computation**
distributed (grid, cloud) and ubiquitous computing

**Connectivity**
internet, communication technologies and social networks

**Pervasive sensing and data**
digital, accessible information on all levels

**New theories of the human brain**
Neuroinformatics, brain-computer interfaces, mind reading

**New business models**
Free tools paid by advertisement, 99+1 principle: 99% free, 1% buys, the revolution in digital economy
The unreasonable effectiveness of data

- Simple linear classifiers based on many features from n-gram representations performs better than elaborate models.
- Unsupervised learning on unlabeled data which are abundant
- The power of linking many different sources
- Semantic interpretation
  - The same meaning can be expressed in many ways – and the same expression can convey many different meanings
  - Shared cognitive and cultural contexts helps the disambiguation of meaning
  - Ontologies: a social construction among people with a common shared motive
  - Classical handcrafted ontology building is infeasible – crowd computing / crowdsourcing are possible

Mission

A cognitive information processing system should optimize itself according to:

The statistical model of the domain, the psycho-physical model of the users, the social context, and the computational resources in time and space.
The cognitive information processing system and its world

Common sense knowledge

Real/virtual environment

Domain knowledge

Multimodal sensors

ACS actions

Human user

Human user

Human

ACS

ACS

ACS

many internal cognitive loops
Information processing and computing

Dynamical, multi-level, integration and learning of
– heterogeneous,
– multi-modal,
– multi-representation (structured/unstructured),
– multi-quality (resolution, noise, validity)
– data, information and human interaction streams

with the purpose of
• achieving relevant specific goals for a set of users,
• and ability to evaluate achievement of goals

using
• new frameworks and architectures and
• computation (platforms, technology, swarm intelligence, grid/cloud computing, crowd computing)
Examples of state of the art along diverse dimensions

- Cognitive radio networks
- Cognitive radar
- Cognitive components
- (Cognitive) sensing networks
- (Cognitive) social network models
- (Cognitive) information retrieval and content management engines
What could the MLSP community contribute

- Bayesian learning as the fundamental learning and information fusion principle
- Nonparametric Bayes
- Signal representation and features
- Sparse models for high-dimensional data
- Dedicated, efficient, robust on-line algorithms for large scale data
- Engineering and demonstration of cognitive information processing platforms
We can only see a short distance ahead, but we can see that there is much to be done

Alan Turing, 1950