ORGANIC: Self-organized recurrent neural learning for language processing

Key Facts

Mission
Establish neurodynamical architectures as viable alternative to statistical methods for speech and handwriting recognition

Website
http://reservoir-computing.org/

Duration
April 1, 2009 – March 31, 2012

Budget
3.52 MEuro (2.7 MEuro EU funding)

Staffing
6 principal investigators
30 researchers (PhD/Postdoc;
17 fully funded by project)
1 administrative assistant

Project Type
EU FP-7, ICT Challenge 2: Cognitive Systems, Interaction, Robots
Collaborative Project (STREP)
Grant agreement No: IST- 231267

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Executive Summary

Current speech recognition technology is based on mathematical-statistical models of language. Although these models have become extremely refined over the last decades, progress in automated speech recognition has become very slow. Human-level speech recognition seems unreachable. The ORGANIC project ventures on an altogether different route toward automated speech recognition: not starting from statistical models of language, but from models of biological neural information processing – from *neurodynamical* models.

ORGANIC will combine a large variety of neurodynamical mechanisms – of signal filtering, learning, short- and long-term memory, dynamical pattern recognition – into a complex neurodynamical "Engine" for speech recognition. A major scientific challenge of ORGANIC lies in the very complexity of the targeted architectures. In order to master the resulting nonlinear dynamical complexity, a special emphasis is put on mechanisms of adaptation, self-stabilization and self-organization. The overall approach is guided by the paradigm of *Reservoir Computing*, a biologically inspired perspective on how arbitrary computations can be learnt and performed in complex artificial neural networks.

R&D activities in ORGANIC will result in

- a much deeper theoretical understanding of how very complex computations, especially those related to language processing, can be robustly and adaptively performed in neurodynamical systems,
- a publicly available *Engine* of programming tools which conforms to recent interface standards for parallel neural system simulations,
- prototype implementations of large-vocabulary speech recognizers and handwriting recognition solutions.

Detailed Objectives

- **Basic blueprints:** Design and proof-of-principle tests of fundamental architecture layouts for hierarchical neural system that can learn multi-scale sequence tasks.
- **Reservoir adaptation:** Investigate mechanisms of adapting reservoirs, which are relevant for optimizing performance on the application benchmarks.
- **Spiking vs. non-spiking neurons, role of noise:** Clarify the functional implications and different learning algorithms for spiking vs. non-spiking neurons and the role of noise.
- **Single-shot model extension, lifelong learning capability:** Develop learning mechanisms which allow an existing cognitive architecture to become extended by new representational items in "single-shot" learning episodes to enable lifelong learning capabilities.
- **Working memory and grammatical processing:** Extend the basic paradigm by mechanisms which function as an index-addressable working memory.
- **Interactive systems:** Extend the adaptive capabilities of human-robot cooperative interaction systems by applying on-line and lifelong learning capabilities.
- **Integration of dynamical mechanisms:** Integrate biologically mechanisms of learning, optimization, adaptation and stabilization into coherent architectures.
- **High performing, well formalized core engine:** Collaborative development of a well formalized and high performing core engine, which will be made publicly accessible.
- **Comply to current FP6 unification initiatives:** Ensure that the Engine integrates with the standards set in the FACETS FP6 IP, and integrate with other existing code.
- **Benchmark repository:** Create a database with temporal, multi-scale benchmark data sets which can be used as an international touchstone for comparing algorithms.
- **Better automated speech recognition and handwriting recognition with reservoir computing:** Develop neural architectures for automated speech and handwriting recognition and efficient learning algorithms in these two target domains.

Expected outcomes and criteria of success

- **Establishing neural dynamics as viable technological alternative for speech and handwriting recognition:** Current technology in these fields is *data-centered*, relying on a statistical analysis of the concerned speech and handwriting data. In ORGANIC, the scientific approach starts from artificial recurrent neural networks, computational neuroscience, cognitive neuroscience and nonlinear dynamics; it may justly be termed *mechanism-centered*. The most fundamental desired outcome of ORGANIC is to prove that its mechanism-centered approach represents a viable alternative to the data-centered one. While the project does not promise to surpass existing technology – that would be preposterous given that current technology reflects many thousands of person-years of effort – , the project aims at neural implementations whose performance *reaches* state-of-the-art levels. Besides performance on benchmarks, reaching this goal will be evaluated by the inclusion of neurodynamical modules into commercial products on the side of the consortium SME partner Planet intelligent systems GmbH.
- **Services to the academic community:** Through a public-domain Engine which adheres to existing standards, through a benchmark repository (public as far as proprietary rights permit), through detailed public documentation of implementations in online technical reports, and through open workshops, the technologies developed in ORGANIC shall be made easily accessible to and useable for the scientific community.
- **Acceptance of the neurodynamical approach in the scientific community** will be demonstrated by peer-reviewed scientific articles. ORGANIC has committed to generate 15 accepted papers in high-ranking journals and 30 accepted contributions to leading conferences.

Consortium

The consortium brings together the original pioneers in reservoir computing, leading researchers in cortical architectures for speech and language processing, speech recognition technologists and an industrial partner at the frontier of automated text recognition:

- the Machine Learning group of Herbert Jaeger (http://www.faculty.jacobs-university.de/hjaeger/) at Jacobs University Bremen, Germany (coordinator),
- the Computational Neuroscience group of Wolfgang Maass (http://www.igi.tugraz.at/maass/) at the Graz University of Technology, Austria,
- the Human and Robot Interactive Cognitive Systems Team of Peter F. Dominey (http://dominey.perso.cegetel.net/) at INSERM Lyon, France,
- the Reservoir Computing Lab of Benjamin Schrauwen (http://snn.elis.ugent.be/benjamin) at the University of Gent, Belgium,
- the Speech Lab of Jean-Pierre Martens (https://speech.elis.ugent.be/) at the University of Gent, Belgium,
- Planet intelligent systems GmbH (http://english.planet.de/), an SME specialized in text recognition solutions, located near Schwerin, Germany.