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New Neural Architectures
and
New Adaptive Evaluation of Chaotic Time Series

Tutorial for the 2008-IEEE-ICAL
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3 Hours

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OUTLINES OF THE TUTORIAL

1. New Neural Architectures

- 1.1 Introduction into New Neural Units (NNU)
- 1.2 Mathematical Notation of NNU and Biological Neuronal Morphology
- 1.3 New Classification of Neural Units
- 1.4 Typical Applications of New Neural Units
- 1.5 Limits and Advantages of NNU over Conventional Neural Network in Applications of Complex System Evaluation

2. New Adaptive Evaluation of Chaotic Time Series

- 2.1 Introduction into New Adaptive Approach to Evaluation of Chaotic Time-Series Based on Nonconventional Neural Units
- 2.2 Applications to Deterministic Chaotic Systems
- 2.3 Limits and Advantages of the Proposed Methodology for Deterministic Chaotic System
- 2.4 Applications to Real Complex Signals
    - o Adaptive Evaluation of Heart Rate Variability (HRV)
- 2.5 Limits and Advantages of the Proposed Methodology for Real Complex Systems

3 DEVELOPMENT OF NEW NEURAL ARCHITECTURES

3.1 BRIEF ON NOTATION OF CONVENTIONAL NEURAL UNITS

3.2 Introduction into Nonconventional Neural Units

3.3 New Universal Classification of Neural Units

3.1.1 Important Attributes of Mathematical Structures of Neural Units

3.1.2 Classification of Neural Units by Nonlinear Aggregating Function

- Static HONNU
- Dynamic HONNU

3.1.3 Classification of Neural Units by Neural Dynamics

3.1.4 Classification of Neural Units by Implementation of Adaptable Time Delays

3.4 Higher-Order Nonlinear Neural Units (HONNU)

3.4.1 Mathematical Notation of HONNU

3.4.2 The Learning Algorithm of HONNU

- The rule
- A simple technique for stable adaptation of dynamic HONNU is shown

3.4.3 Demonstration of Typical Applications of HONNU

3.4.4 Limits and Advantages HONNU for Evaluation of Complex Systems

3.5 Time-Delay Dynamic Neural Units (Tmd-DNU*)*

3.5.1 Mathematical Notation of Tmd-DNU

3.5.2 The Learning Algorithm of Tmd-DNU

- The rule
- A technique for stable adaptation of dynamic Tmd-DNU

3.5.3 Demonstration of Typical Applications of Tmd-DNU

3.5.4 Limits and Advantages of Tmd-DNU for Evaluation of Complex Systems

3.6 Synaptic Neural Operation and Somatic Neural Operation of New Neural Units

Emerging aspects resulting from the mathematical notation of new neural units with nonlinear aggregating function when compared to biological neuronal morphology are shown. Impacts to terminology and general conception of the synaptic neural operation of HONNU and TmD-HONNU are discussed.

4 NEW ADAPTIVE APPROACH FOR EVALUATION OF COMPLEX TIME-SERIES

4.1 Brief Introduction into Evaluation of Complex Time Series by Common Nonlinear Methods

4.1.1 Brief on Common Nonlinear Methods

- Correlation Dimension
- Liapunov Exponents
- Recurrence Plot

4.1.2 Issues of Evaluation of Deterministic Chaotic Systems by Existing Nonlinear Methods

- Too complex and too nonlinear systems
- Multi-attractor behavior of chaotic systems

4.1.3 Issues of Evaluation of Real Complex Systems by Existing Nonlinear Methods

- Multi-attractor behavior of real complex systems
    - Multi-attractor behavior of heart rate variability
- Openness of real systems (unknown inputs)
- Data length
- E.g., evaluation of HRV

4.2 Evaluation of Complex Time Series using Nonconventional Neural Units

4.2.1 Development of Special Neural Units with Input Signal Preprocessor – HRV-HONNU

The increase of an approximating capability of neural units utilizing the principle of forced nonlinear adaptive oscillators is demonstrated. Stability maintaining adaptation technique for HRV-HONNU is presented as based on combination of utilization first both static and neural units.

4.2.2 Methodology of Adaptive Evaluation of Complex Time Series – Monitor Plot

New methodology of adaptive and universal evaluation of complex dynamic systems is presented. The methodology is based on observation and evaluation of unusual increments of neural parameters sample by sample in a real time.

4.3 Applications

4.3.1 Adaptive Evaluation of Deterministic Chaotic Systems

4.3.2 Adaptive Beat-by-Beat Monitoring of Changes in Variability of Real Complex Signals

4.4 Limitations and Advantages Summary

Principal advantages over common nonlinear methods such as Correlation Dimension, Liapunov Exponents, or Recurrence Plot are discussed as demonstrated on applications in section 4.3.

5 SUMMARY AND FUTURE PROSPECTS

5.1 Nonconventional Neural Architectures

5.2 Adaptive Evaluation of Complex Systems Using New Neural Units

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Expected Audience

The presentation would be addressed to general audience interested in new trends in the field of artificial neural networks and evaluation of complex, especially, chaotic and complex systems.

The introduction to new neural architectures, the learning algorithm, and the applications to complex system approximation is intended to be comprehensible also to undergraduate and graduate students with common knowledge of continuous and discrete dynamic systems.

Graduate students and experts can be attracted by the presentation of new approach to classification of neural architectures and comparison of their mathematical structure to biological neuronal morphology with impacts to terminology of artificial neural units with nonlinear aggregating functions.

The presentation of the new methodology of adaptive evaluation of complex systems and its applications to real complex signals such as heart rate variability might possibly attract also expert researchers.

The limits and advantages over common nonlinear methods such as correlation dimension, Lyapunov exponents, or Recurrence Plot can attract also researchers interested in various fields such as signal processing and so on.

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