Novel techniques for improving NNetEn entropy calculation for short and noisy time series

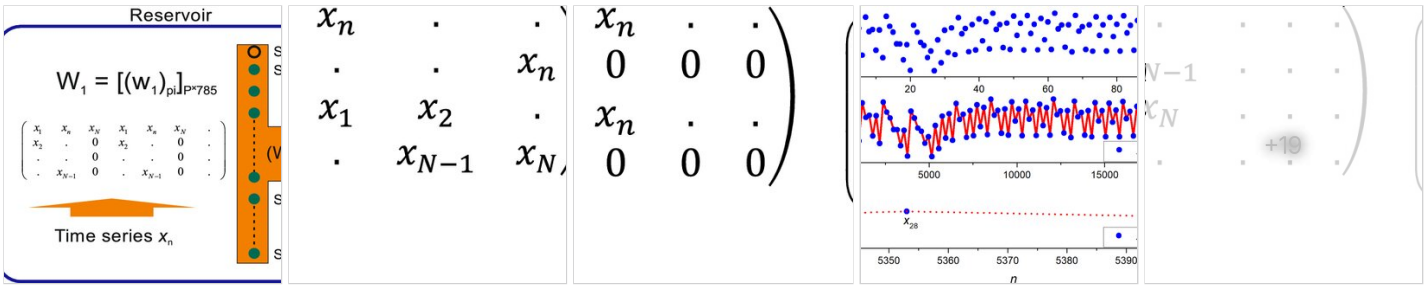
February 2023 · 111(10):1-22
DOI: 10.1007/s11071-023-08298-w

Hanif Heidari · Andrei Velichko · Prof Dr.M. Murugappan · Muhammad E. H. Chowdhury

Abstract and figures

Entropy is a fundamental concept in the field of information theory. During measurement, conventional entropy measures are susceptible to length and amplitude changes in time series. A new entropy metric, neural network entropy (NNetEn), has been developed to overcome these limitations. NNetEn entropy is computed using a modified LogNNet neural network classification model. The algorithm contains a reservoir matrix of N = 19,625 elements that must be filled with the given data. A substantial number of practical time series have fewer elements than 19,625. The contribution of this paper is threefold. Firstly, this work investigates different methods of filling the reservoir with time series (signal) elements. The reservoir filling method determines the accuracy of the entropy estimation by convolution of the study time series and LogNNet test data. The present study proposes 6 methods for filling the reservoir for time series of any length 5 ≤ N ≤ 19,625. Two of them (Method 3 and Method 6) employ the novel approach of stretching the time series to create intermediate elements that complement it, but do not change its dynamics. The most reliable methods for short-time series are Method 3 and Method 5. The second part of the study examines the influence of noise and constant bias on entropy values. In addition to external noise, the hyperparameter (bias) used in entropy calculation also plays a critical role. Our study examines three different time series data types (chaotic, periodic, and binary) with different dynamic properties, Signal-to-Noise Ratio (SNR), and offsets. The NNetEn entropy calculation errors are less than 10% when SNR is greater than 30 dB, and entropy decreases with an increase in the bias component. The third part of the article analyzes real-time biosignal EEG data collected from emotion recognition experiments. The NNetEn measures show robustness under low-amplitude noise using various filters. Thus, NNetEn measures entropy effectively when applied to real-world environments with ambient noise, white noise, and 1/f noise.

Read more



Page 1

Nonlinear Dyn (2023) 111:9305–9326
https://doi.org/10.1007/s11071-023-08298-w

ORIGINAL PAPER

Novel techniques for improving NNetEn entropy calculation for short and noisy time series

Hanif Heidari · Andrei Velichko · Murugappan Murugappan · Muhammad E. H. Chowdhury

Received: 18 November 2022 / Accepted: 26 January 2023 / Published online: 11 February 2023

Abstract Entropy is a fundamental concept in the field of information theory. During measurement, conventional entropy measures are susceptible to length and amplitude changes in time series. A new entropy metric, neural network entropy (NNetEn), has been developed to overcome these limitations. NNetEn entropy is computed using a modified LogNNet neural network classification model. The algorithm contains a reservoir matrix of $N = 19{,}625$ elements that must be filled with the given data. A substantial number of practical time series have fewer elements than 19,625. The contribution of this paper is threefold. Firstly, this work investigates different methods of filling the reservoir with time series (signal) elements. The reservoir filling method determines the accuracy of the entropy estimation by convolution of the study time series and LogNNet test data. The present study proposes 6 methods for filling the reservoir for time series of any length $5 \leq N \leq 19{,}625$. Two of them (Method 3 and Method 6) employ the novel approach of stretching the time series to create intermediate elements that complement it, but do not change its dynamics. The most reliable methods for short-time series are Method 3 and Method 5. The second part of the study examines the influence of noise and constant bias on entropy values. In addition to external noise, the hyperparameter (bias) used in entropy calculation also plays a

H. Heidari
Department of Applied Mathematics, Damghan University, P. O. Box 36715-364, Damghan, Iran

A. Velichko
Institute of Physics and Technology, Petrozavodsk State University, 31 Lenina Str, Petrozavodsk, Russia 185910

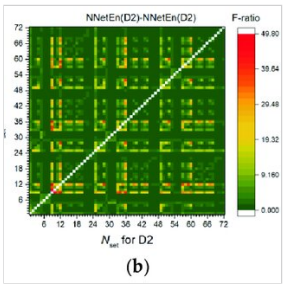
M. Murugappan (✉)
Department of Electronics and Communication Engineering, Kuwait College of Science and Technology, Block 4, 13133 Doha, Kuwait
e-mail: m.murugappan@kcst.edu.kw; m.murugappan@gmail.com

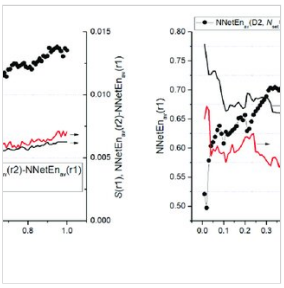
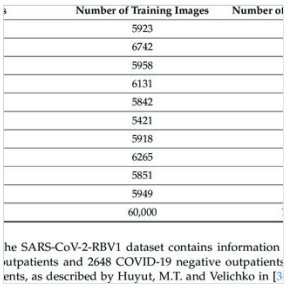
M. Murugappan
Department of Electronics and Communication Engineering, Vels Institute of Sciences, Technology, and Advanced Studies, Chennai, India

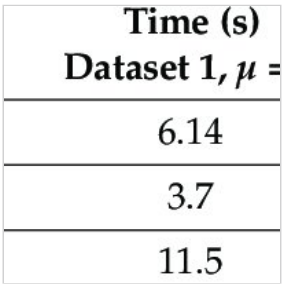
M. Murugappan
Center for Unmanned Aerial Vehicles (CoUAV), Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia

M. E. H. Chowdhury
Department of Electrical Engineering, College of Engineering, Qatar University, 2713 Doha, Qatar

Similar research





Neural Network Entropy (NNetEn): Entropy-Based EEG Signal and Chaotic Time Series Classification, Python Package for NNetEn Calculation

Article Full-text available

May 2023 · 215 Reads · 9 Citations

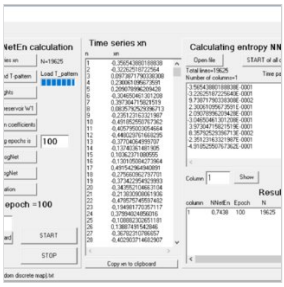
Algorithms

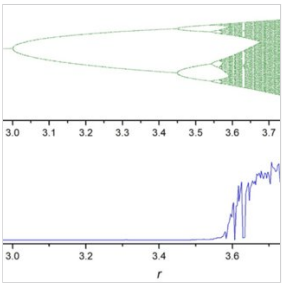
Andrei Velichko · Maksim Belyaev · Yuriy A. Izotov · [...] · Hanif Heidari

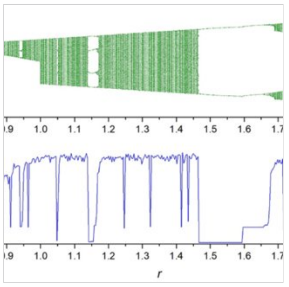
Entropy measures are effective features for time series classification problems. Traditional entropy measures, such as Shannon entropy, use probability distribution function. However, for the effective separation of time series, new entropy estimation methods are required to characterize the chaotic dynamic of the system. Our concept of Neural Network Entropy (NNetEn) is based on the classification of special...

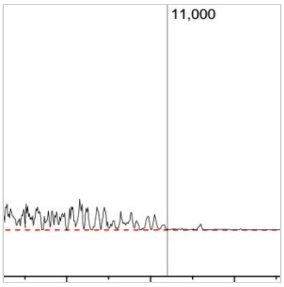
Read more

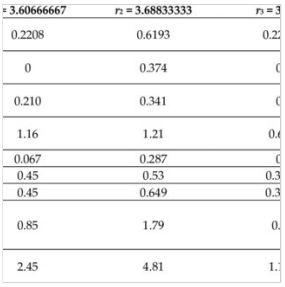
View











A Method for Estimating the Entropy of Time Series Using Artificial Neural Networks

Article Full-text available

October 2021 · 508 Reads · 38 Citations

Entropy

Andrei Velichko · Hanif Heidari

Measuring the predictability and complexity of time series using entropy is essential tool designing and controlling a nonlinear system. However, the existing methods have some drawbacks related to the strong dependence of entropy on the parameters of the methods. To overcome these difficulties, this study proposes a new method for estimating the entropy of a time series using the LogNNet neural network...

Read more

View

Novel techniques for improvement the NNetEn entropy calculation for short and noisy time series

Preprint

February 2022 · 39 Reads

Hanif Heidari · Andrei Velichko

Entropy is a fundamental concept of information theory. It is widely used in the analysis of analog and digital signals. Conventional entropy measures have drawbacks, such as sensitivity to the length and amplitude of time series and low robustness to external noise. Recently, the NNetEn entropy measure has been introduced to overcome these problems. The NNetEn entropy uses a modified version of the LogNNet...

Read more

View

Neural Network Entropy (NNetEn): EEG Signals and Chaotic Time Series Separation by Entropy Features, Python Package for NNetEn Calculation

Preprint

March 2023 · 70 Reads

Andrei Velichko · Maksim Belyaev · Yuriy A. Izotov · [...] · Hanif Heidari

Entropy measures are effective features for time series classification problems. Traditional entropy measures, such as Shannon entropy, use probability distribution function. However, for the effective separation of time series, new entropy estimation methods are required to characterize the chaotic dynamic of the system. Our concept of Neural Network Entropy (NNetEn) is based on the classification of special...

Read more

View

A Method for Estimating the Entropy of Time Series Using Artificial Neural Networks

Preprint

July 2021 · 45 Reads

Andrei Velichko · Hanif Heidari

Measuring the predictability and complexity of time series is an essential tool in designing and controlling the nonlinear system. There exist different entropy measures in the literature to analyze the predictability and complexity of time series. However, these measures have some drawbacks especially in short time series. To overcome the difficulties, this paper proposes a new method for estimating the entropy of a tim...

Read more

View
