Comparative Analysis of Eleven Dynamic Artificial Neural Networks

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Introduction

In the evolving landscape of machine learning, dynamic artificial neural networks (DNN) have emerged as a powerful tool to process sequential data. Their unique ability to incorporate temporal information positions them as critical tools in tackling challenges in diverse fields such as natural language processing, financial forecasting, and human motion recognition. Despite the growing importance of DNN, the characteristics of different architectures remain unexplored.

Aims

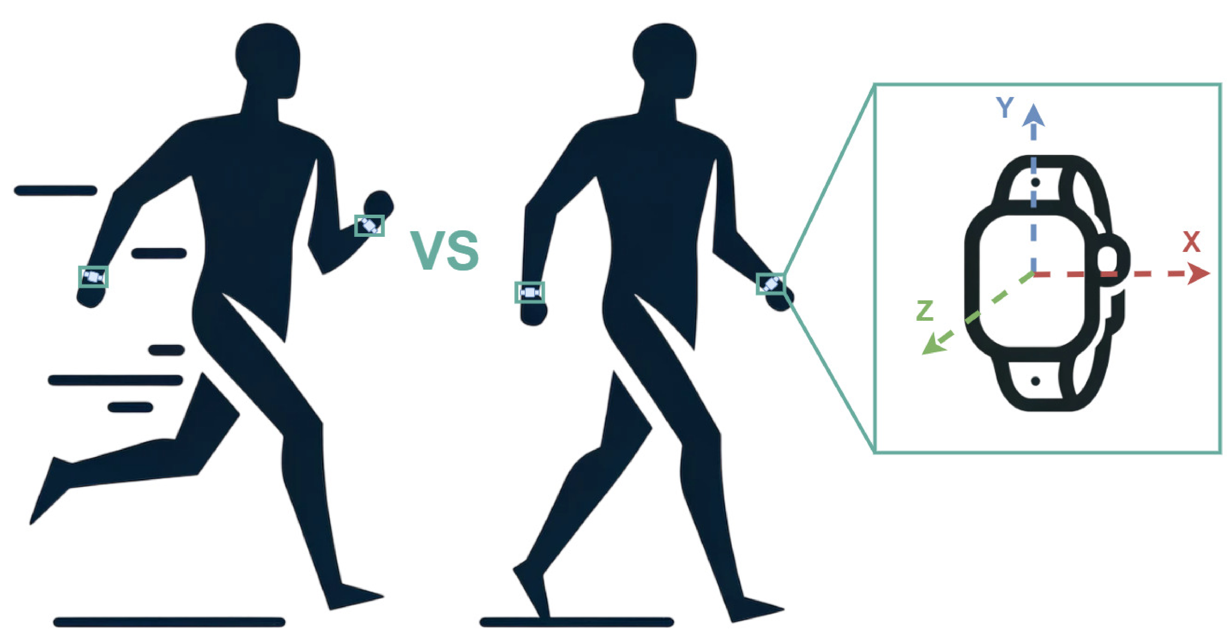
The goal of the study – to provide a detailed comparison of DNNs for time-series data classification tasks through the lens of model complexity and performance metrics that include accuracy and learning efficiency.

The main objectives:

a) prepare a suitable dataset for different DNN comparisons;
b) implement the best-known DNN architectures for a time-series data based classification task;
c) train, validate, test, and select the best representatives from the sufficient set of DNN implementations;
d) analyze key features of each DNN, including model complexity, accuracy, and learning efficiency.

A Dataset Preparation

The prepared dataset is taken from the Kaggle open-source database that is actively used for numerous competitions and research. The dataset includes time-series data obtained from accelerometers attached to the left and right wrists of individuals engaged in two physical activities: running or walking.



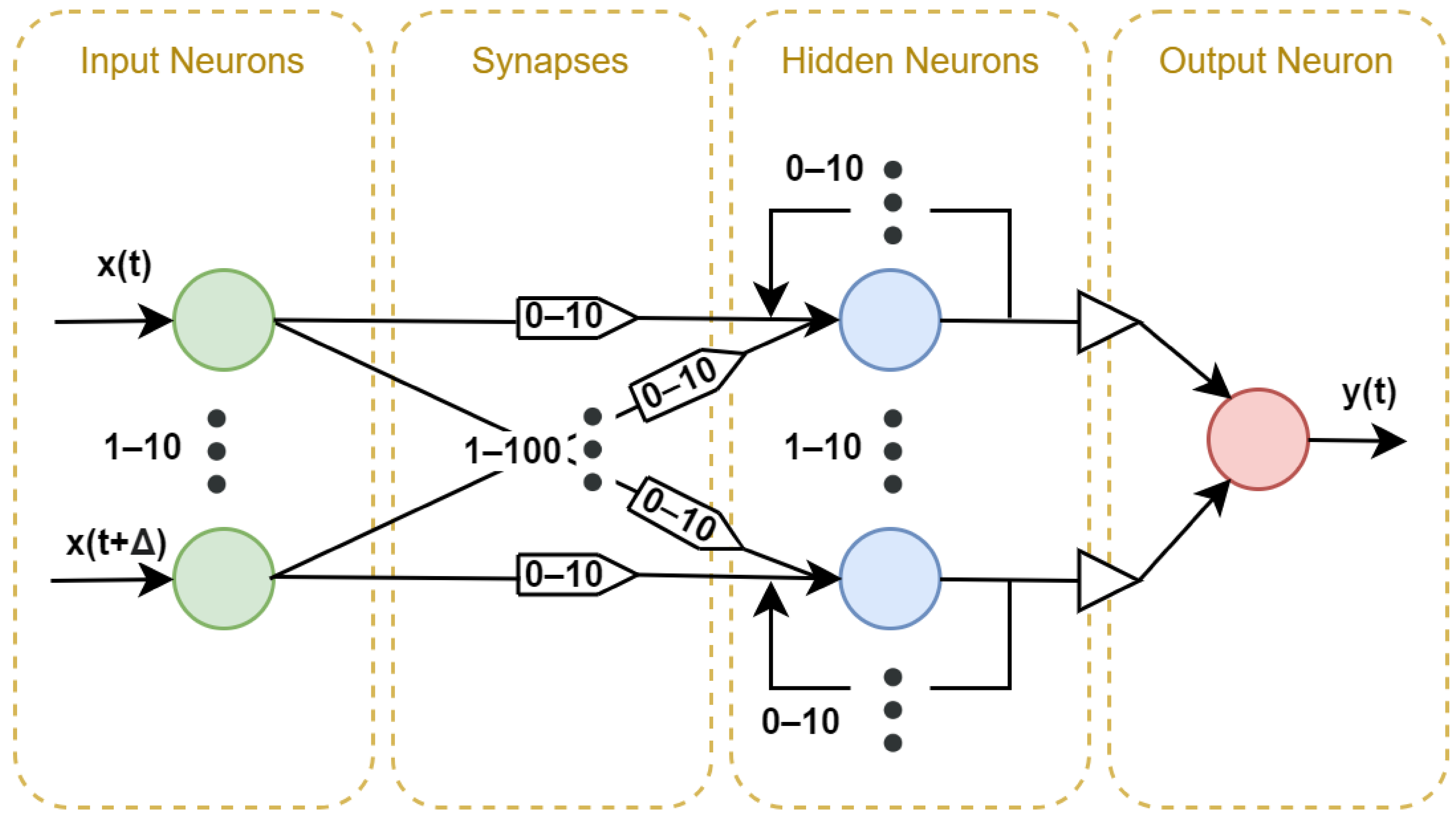
Accelerometer data collection from walking or running individual

Before using the data set for DNN training and comparison, the magnitude of the accelerometer's x, y, and z coordinates was computed to improve the accuracy and relevance of the input data.

DNNs Implementation

Based on analysis of the research literature covering 35 years,i.e., 1987 to present, the 11 DNN architectures were selected for comparative analysis and implemented within a MATLAB framework.

To limit excessive comparisons, each DNN was set to a three-layer generalization scheme. Nevertheless, the capabilities of each DNN to tackle the selected classification problem were investigated broadly, by varying the number of input and/or hidden neurons (1–10), and the order of forward, and/or recurrent synapses (1–10). In a total of 8 300 different structures derived from 11 architectures were simulated.



Generalization scheme of investigated 11 DNNs architectures

Results

All different DNN structures considered were 100 times: randomly initialized, trained with validation, and tested. The best – of the minimal structure size and the highest prediction accuracy of physical activity, representatives of each DNN architecture were selected and their results are shown in the table.

Key features of the minimal-size DNN architectures manifesting the highest accuracy (ACC)

DNN Type[1]	Parameters, nmb.				ACC[2], %	Epoch[2], nmb.
	Act. Func.	Weight	Delay	Total[2]		
Finite Impulse Response (FIR)	2	5	5	12	98.73	125
Gamma Memory	2	5	9	16	99.29	164
Simplified FIR	3	16	2	21	99.72	315
Lattice Ladder	5	20	7	32	99.29	804
Time Delay	5	24	5	34	98.02	65
Bi-directional	6	25	4	35	98.45	28
Recurrent	5	28	3	36	97.74	48
Time Derivative	6	30	5	41	97.31	1213
Infinite Impulse Response	11	80	3	94	98.73	205
Gated Recurrent Unit	10	112	3	125	98.31	44
Long Short-Term Memory	21	146	5	172	98.31	22

In blue: 1 – the best DNN according to individual criteria, 2 – the best three values in each criteria.

Conclusions

The comparative results of 11 DNN architectures use for two accelerometers data based prediction of a person's physical activity task grounds that:

1. The FIR DNN possesses the smallest necessary to-use structure (12 parameters), Simplified FIR DNN achieves the highest prediction accuracy (99.72%), while Long Short-Term Memory has the quickest training time (22 epochs).

2. According to the two joint criteria – the structure size and prediction accuracy, the best are Simplified FIR (3rd, 1st results) and the Gamma Memory (2nd, 2nd results).

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