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Utilizing long short-term memory neural network for effective prediction of electrocardiosignals and pathology identification

E.A. Denisova[1✉], A.A. Kordyukova[1], D.O. Sevakov[1,2]

[1] Institute for Analytical Instrumentation RAS, St. Petersburg, Russia;

[2] Saint Petersburg State University of Aerospace Instrumentation, St. Petersburg, Russia

✉ Tiranderel@yandex.ru

Abstract. Currently, neural networks (NN) are becoming an increasingly common tool in the field of diagnosis of diseases of the cardiovascular system. These architectures demonstrate high accuracy in analyzing complex data such as electrocardiosignals (ECS). Among various NN types, long-term memory (LSTM) stands out as a powerful method for analyzing time series. This technology has the ability to remember long-term dependencies in data, which makes it particularly useful for processing sequential data, including ECS. However, using the standard electrocardiography (ECG) method, it is impossible to obtain complete information about the stages of development of cardiovascular pathologies. The current trend towards increasing the informative value of the ECS has led to the development of a new method of ultra-high resolution electrocardiography (UHR ECG). This method significantly improves the detection of pathologies in the cardiovascular system in various areas of ECG treatment and also allows the detection of early markers of acute myocardial ischemia. UHR ECG provides an opportunity for a more detailed analysis of cardiac signals, which can be crucial in the early diagnosis and treatment of cardiovascular diseases. In this work, a six-layer LSTM was used to predict the shape of ECS obtained using the UHR ECG method in experimental rats. The experiments were aimed at modeling acute myocardial ischemia in order to identify trends in the development of markers of this pathology. The results of the study may contribute to the creation of more effective methods for diagnosing and monitoring cardiovascular diseases.

Keywords: ultra-high resolution electrocardiography, electrocardiosignal, neural network, prediction, long short-term memory networks, coronary heart disease, ischemia

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Материалы конференции
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Использование нейронной сети с долгой краткосрочной памятью для эффективного прогнозирования электрокардиосигналов и идентификации патологии

Е.А. Денисова[1]✉, А.А. Кордюкова[1], Д.О. Шевяков[1,2]

[1] Институт аналитического приборостроения РАН, Санкт-Петербург, Россия;

[2] Санкт-Петербургский государственный университет аэрокосмического приборостроения, Санкт-Петербург, Россия

✉ Tiranderel@yandex.ru

Аннотация. Среди различных типов нейронных сетей (НС) сети с долгой краткосрочной памятью (LSTM) обладают способностью запоминать долгосрочные зависимости в данных, что делает их особенно полезной для обработки длинных последовательных данных, включая электрокардиосигналы (ЭКС). Однако, используя стандартный метод электрокардиографии (ЭКГ), невозможно получить полную информацию о стадиях развития сердечно-сосудистых патологий, включая ишемическую болезнь сердца. Современная тенденция к повышению информативности ЭКГ привела к разработке нового метода электрокардиографии сверхвысокого разрешения (ЭКГ СВР). В этой работе была использована шестислойная сеть с долгой краткосрочной памятью для прогнозирования формы ЭКС, полученных с помощью метода ЭКГ СВР у подопытных крыс в ходе экспериментов по моделированию острой ишемии миокарда.

Ключевые слова: электрокардиография сверхвысокого разрешения, электрокардиосигнал, нейронная сеть, прогнозирование, долгая краткосрочная память, ишемическая болезнь сердца, ишемия

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Introduction

The analysis of signals obtained using electrocardiography (ECG) using neural networks (NN) is one of the most promising areas in the field of cardiology and medical diagnostics. It is expected that in the future, combining these technologies will become the norm in medical practice [1–3]. ECG is a key tool for diagnosing various diseases of the cardiovascular system (CVS), including coronary heart disease and myocardial infarction. However, using the standard ECG method, it is impossible to obtain complete information about the stages of development of cardiac muscle pathologies [4].

The current trend towards increasing the informative value of the ECG has led to the creation of a new proprietary technique of ultra-high resolution electrocardiography (UHR ECG), the purpose of which is to identify pathological changes in the CVS in classical areas of electrocardiosignal (ECS) processing and in areas that are usually considered artifacts [5]. The method is being developed by the team of one of the leading scientific schools of the Russian Federation, Radioelectronic and Information Tools for assessing the physiological parameters of living Systems.

When using the UHR ECG method, the signal is recorded using two channels: a low-frequency (LF), similar to a standard ECG, and a high-frequency (HF) containing micropotentials. According to the hypothesis described in the study [5], the main marker of the development of myocardial ischemia in experimental animals is a decrease in the average spectral power density of the HF part of the spectrum of the received signal. And one of the key tasks in these studies is to predict the shape of the UHR ECS based on existing recordings in order to identify and capture changes associated with the pathology at an early stage. In this work, six-level long short-term memory (LSTM) was used to predict the shape of UHR ECS. To train and test the NN, a set of data was used, obtained from Vistar experimental rats during experiments on modeling acute myocardial ischemia at the Institute of Experimental Medicine of the Almazov National Research Medical University [6].

Materials and Methods

A recurrent neural network with LSTM has been applied to predict the shape of the UHR ECS based on the current context. LSTMs are specifically designed to work with consistent data and effectively identify long-term dependencies. The LSTM architecture includes special "memory cells" that can hold information for a long time and control the process of forgetting it. Each such cell consists of three main components: an inlet valve, a forgetting valve, and an outlet valve. These elements help determine which information will be saved, which will be forgotten, and which will be transmitted to the network outputs [7].

To train and test the model, a dataset was collected, including 80 records of UHR ECS. The training sample consisted of 98% of the data, and the test sample consisted of the remaining 2%, which were used to adjust the hyperparameters. During preprocessing, the UHR ECS recordings were filtered according to the algorithm described in [8]. In addition, each signal was split into fragments lasting 1 second (6250 samples). These studies are conducted on the basis of Laboratory 235 "Radio- and optoelectronic devices for the diagnosis of human diseases" of the Institute of Analytical Instrumentation of the Russian Academy of Sciences.

Results and Discussion

The a six-layer LSTM has been trained for 50 epochs. The mean absolute error (MAE), which shows how much, on average, the model's predictions deviate from the actual values, was 0.0300. For the validation dataset, the MAE is 0.0304, which indicates a good accuracy of the trained model.

As an example, Fig. 1 shows the result of using LSTM to predict the shape of UHR ECS during the experiment. The gray line in the figure marks a fragment of the UHR ECS, the shape of which the trained model was supposed to predict, and the black line shows the predicted signal obtained as a result of using the model.

The graph shows that the predicted signal largely coincides with the original signal. This indicates the high accuracy of the LSTM model in predicting ECS patterns, which is a positive result.

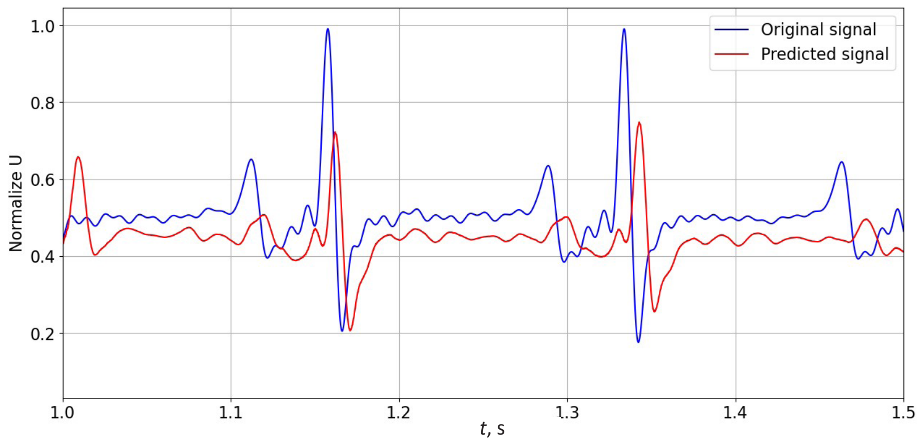

Fig. 1. Original and predicted UHR ECS

It should also be noted that in the area of the isoline, the received signal has fewer parasitic oscillations that are not characteristic peaks of the ECS wave, which indicates that the model is able to extract diagnostically significant information against the background of noise and interference during training.

Conclusion

In the course of the study, it was shown that neural networks, in particular LSTM, demonstrate high accuracy in analyzing complex data, such as ECS obtained using the UHR ECG method, due to the ability to remember long-term data dependencies. The results obtained show that the model is able to accurately predict changes in the shape of the EC during experiments on modeling acute myocardial ischemia in experimental rats, which is crucial for the early detection of markers of the development of the pathology under study. Using LSTM for ECS analysis offers a promising strategy that can significantly improve the diagnosis and monitoring of heart disease, especially with regard to early detection of coronary artery disease.

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THE AUTHORS

DENISOVA Elena A.
Tiranderel@yandex.ru
ORCID: 0000-0003-0329-2881

SEVAKOV Daniil O.
sevakovdaniil@gmail.com
ORCID: 0000-0001-5609-4091

KORDYUKOVA Anna A.
annygm00@mail.ru
ORCID: 0000-0002-6099-4276

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