manual classification performed by an expert is also strongly influenced by his/her experience. This fact can lead to high heterogeneity of the classifications.

In order to automate, simplify and unify the sleep classifications, a huge effort to develop automated sleep/wake stagers has been made in the last decades [1], [2], [3], [4]. Three main tasks can be point out in the research activities: implementation of algorithms for artifact identification and minimization, choice of adequate type and structure of an automatic classifier, and extraction of relevant features representing the state of the analyzed object.

This article presents application of a two-step classification system on a set of rat polysomnographic recordings. The automatic system used takes into account presence of possible artifacts and performs automatic classification using features extracted from available artifact-free signals. The idea of the classification is to use appropriate classifier for each epoch to be classified, depending on the quality of the monitored signals.

The outline of the article is the following. The automatic system for analysis of polysomnographic recordings is presented in the second section. The database of recordings used is presented in the third section. Then, final results are presented and discussed in the section number four. At the end, short conclusions are presented.

2 SYSTEM FOR AUTOMATIC CLASSIFICATION

The process of automatic sleep staging typically consists in succession of several steps – artifact processing, extraction of significant features from epochs of the polysomnographic recordings, and application of the features as inputs to the classifier. In this project, a complex two-step automatic system was used to analyse the polysomnographic recordings. The two-step classification system has been previously evaluated on human polysomnographic recordings [5].

2.1 Two-step System

The two-step automatic system separates artifact identification procedure from the stage of classification. Thus, it can combine the results of artifact identification procedure with adequate automatic classification using relevant features extracted from the available artifact-free signals.

Artifact detection

The first step consists in artifact analysis of the signals and aims to determine if any artifact is present in the epoch to be classified. In our research, polysomnographic recordings consist of EEG and EMG signals.

In order to allow effective identification of short artifacts which are rather common in polysomnographic recordings, the original time resolution has been changed. Detection algorithm dealing with shorter segments can be more precise in localization of the artifacts and also thriftier of the data. Each epoch with original length of 30sec has been split into fifteen 2sec segments. If no artifact is present in a signal or only a small part of a signal in the 30sec epoch (less than four 2sec segments) is artifacted, the epoch is marked as “artifact-free” and features can be computed from the parts of the signal which are not confused by artifacts. The artifacted segments of a signal are removed. If too large part of a signal in the epoch is artifacted (more than three 2-sec segments), the epoch is marked as "artifacted" and is completely removed from the classification. This strategy ensures that only the signals that can be used to classify the current epoch are selected for the second step of the analysis – automatic classification.

Artifact identification procedure has been performed using a specialized PRANA Software. This tool is equipped with a universal automatic artifact detection algorithm which is inspired by the work of Bruner [6]. The algorithm can use either fixed or adaptive thresholds for artifact identification. The algorithm was tuned so as to identify the artifacts most frequently present in the polysomnographic signals, using physiological knowledge. The setting of the algorithms could not been evaluated properly, since the available polysomnographic database did not contain any artifact analysis performed visually by an expert. For the need of the actual research, eight different artifacts were automatically detected, six of them (overflow, electrode detachment, power line artifact, ECG artifact, high-frequency artifact, flat-line) being detected using a priori fixed thresholds and two (low-frequency artifact, muscular activity) using adaptive thresholds. More details about artifact identification strategy can be seen in [5], [7].

Classification

The second step of the whole analysis represents the automatic classification. During the classification, relevant features are extracted from the artifact-free signals and then used in an appropriate automatic classifier. The decision system is generally formed by a bank of different classifiers: one classifier for each combination of monitored signals. Selection of the proper classifier depends on the results of the artifact identification procedure performed on the signals.

Since the polysomnographic recordings, the bank of classifiers contains only two classifiers corresponding to the two possible combinations of signals: EEG only and EEG and EMG. The EEG signal is considered to be indispensable for the automatic sleep/wake stage classification, so if the EEG signal is artifacted, the epoch cannot be classified by the system.

Depending on the previous research studies [4], [5], [7], artificial neural networks have been selected as automatic classifiers used in this research. Two architectures of supervised artificial neural networks have been used for the classification: feedforward neural networks and radial basis neural networks.

Feedforward neural networks with three layers represent the first classifier tested in the research. Number of neurons in the first layer is determined by actual number of input features extracted from the epoch to be classified. Neurons in the first layer are equipped with hyperbolic tangent transfer function. The second layer of the network contains 6 neurons equipped with logarithmic sigmoid transfer function. The output layer of the network consists of 3 neurons each corresponding to one sleep/wake stage (wake, NREM sleep, and REM sleep). The transfer function of the neurons in the output layer is a hyperbolic tangent.