ECG Signal Recognition Methods to Determine an Exposure to Magnetic Field

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Abstract: *The paper presents a methodology of research on the magnetic field influence on the human body, based on pattern recognition algorithms. A group of 15 volunteers has been exposed to a 50Hz magnetic field of strength 60 A/m. There were recorded 30 ECG signals, 2 for each experiment participant. The first signal was recorded before an exposure to a magnetic field, and the second signal immediately after exposure to the field. The first signal was recorded before an exposure to a magnetic field, and the second signal immediately after exposure, creating two classes of signals. In the paper we discuss supervised classification methods. The purpose of these methods is to detect whether the exposure to a magnetic field occurred, basing on the automatic analysis of the ECG signal.*

Keywords: *pattern recognition, electrocardiogram, magnetic field*

1. Introduction

The phenomenon of magnetic field effect on the human body has many open points yet. The possible effects of exposure to the magnetic component of the electromagnetic field have a dual nature [1], can be both positive and negative. To examine this phenomenon and the possibility of detection of exposure to the field after some, but short, time is of the utmost importance, since we are surrounded by hundreds of electrical devices. The electrical and electronic devices emit a magnetic field, whose effect on the body we hardly know.

The experiment was designed to build a classifier, which could automatically (without any help from outside) detect whether a person has been exposed to remain in a magnetic field. During the experiment, a group of 15 volunteers has been exposed to a 50Hz magnetic field of strength 60 A/m. The strength 60 A/m is permissible [2] for the constant exposure. Every volunteer had 2 ECG recordings, so the total number of signals was 30. A learning set contains 20 ECG signals and a testing set – 10 ECG. For details of classifier learning procedure, see the section 2.1.

2. Detection of exposure to magnetic field

Our goal was to develop a recognition algorithm [3-6] that will indicate whether the ECG signal is measured before or after exposure to a magnetic field. We want the algorithm to decide independently for a new ECG whether the person has just been exposed to the magnetic field or not. The construction of such a classification algorithm is relied on a supervised learning method.

2.1. Supervised learning of classifier

Supervised learning is a procedure of classifier learning [4-6]. The classifier, e.g. k-Nearest Neighbors algorithm, is learning on the basis of previously measured data; in our case the set of ECG signals [3,4], divided into two classes:

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- **class 1**: signals recorded in the absence of exposure to the field,
- **class 2**: signal recorded immediately after exposure to the field.

The supervised learning by the data (ECG signals) in the learning set is the first stage of the classification. The schema of this stage is shown in the Fig. 1.

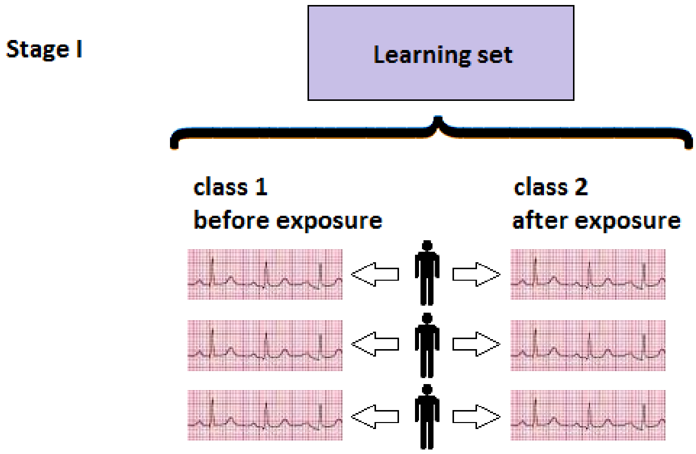

Fig. 1. The first stage of classification. The supervised learning of a classifier by the data in two classes (before and after exposure to the magnetic field).

After the learning, classifier is ready to use. It is tested for a new set of ECG signals recorded for volunteers before and after exposure to the magnetic field. The new set of data is called testing set. In the second stage of classification (see Fig. 2), the classification algorithm can determine alone the class of signal, basing on the knowledge hidden in the data from the learning set. Different recognition algorithms use that knowledge in different way, what depends on the structure of classifier.

The main characteristic, common for every classifier, is the misclassification risk. The risk is the expected loss when the classifier decision is incorrect. For statistical classification problems, the risk of classifier is usually unknown and its value can be only estimated. The estimation of the risk is described in the section 3.2.

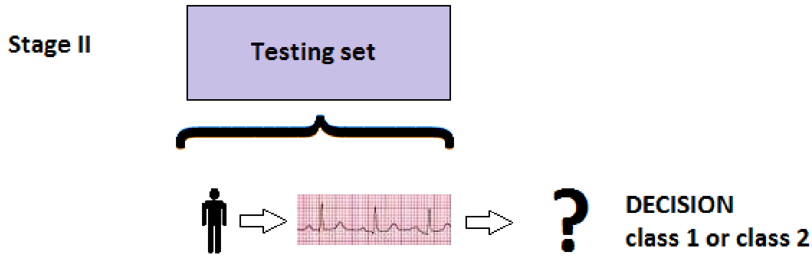

Fig. 2. The second stage of classification. The classifier chooses a class.

2.2. Estimation of the risk

The risk estimation is based on the testing set, containing *n* ECG signals, and can be performed as follows. The testing set and the learning set are disjoint, i.e. if the signal appeared in the learning set, then it was not contained in the testing set. Firstly, there are $n=10$ independent classifications made for every signal from the testing set. Then we compare the results of the classification (class chosen by algorithm) with the real signal classes (class 1 or class 2). There are several rates that can be calculated:

- **False positive rate α** (type I error)

$$\alpha = \mathrm{FP}/(\mathrm{FP}+\mathrm{TN}), \quad (1)$$

- **False negative rate β** (type II error)

$$\beta = \mathrm{FN}/(\mathrm{TP}+\mathrm{FN}), \quad (2)$$

- **Misclassification risk R**

$$\mathrm{R} = (\mathrm{FP}+\mathrm{FN})/(\mathrm{TP}+\mathrm{TN}+\mathrm{FP}+\mathrm{FN}), \quad (3)$$

- **Sensitivity Se**

$$\mathrm{Se} = 1 - \beta = \mathrm{TP}/(\mathrm{TP}+\mathrm{FN}), \quad (4)$$

- **Specificity Sp**

$$\mathrm{Sp} = 1 - \alpha = \mathrm{TN}/(\mathrm{FP}+\mathrm{TN}), \quad (5)$$

where FP is the number of cases that there was no exposure to field, but classifier had detected it (had chosen class 2). FN is the number of cases that there was exposure to field, but classifier had not detected it (had chosen class 1). TP is the number of cases that there was exposure to field and the classifier had correctly detected it (had chosen class 2). TF is the number of cases that there was no exposure to field and the classifier had not detected the field (had chosen class 1). Obviously, the sum of all cases in the four situations gives us the number of signal in the testing set, i.e.

$$\mathrm{TP}+\mathrm{TN}+\mathrm{FP}+\mathrm{FN} = \mathrm{n}. \quad (6)$$

It is desirable to use classifiers with low values of the risk. But the sensitivity (4) and the specificity (5) rates should be as high as possible. High sensitivity means that the large percentage of ECG signals were correctly recognized as recorded after exposure to the field. However, high specificity is achieved if the large percentage of ECG signals were correctly recognized as recorded before exposure to the field. The rates, listed above, allow to choose such a classifier, which the best meets the specified conditions.

3. Summary and future work

The presented research methodology is applied to the constantly growing collection of ECG signals (for subsequent volunteers). There is a plan to gather at least 200 ECG signals, for 100 volunteers, who agree to be exposed to a 50 Hz magnetic field of strength 60 A/m.

The detection of the staying in the magnetic field may be useful if there will be a law regulations, defining the field strength limits in conjunction with the time limits.

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METODY ROZPOZNAWANIA SYGNAŁÓW EKG W CELU OKREŚLENIA EKSPOZYCJI NA POLE MAGNETYCZNE

Wpływ pola magnetycznego na organizm ludzki może być zarówno pozytywny, jak i negatywny. Możliwe, że w przyszłości, gdy zostanie doprecyzowane prawo dotyczące bezpiecznej ekspozycji na pole magnetyczne, wykrywanie post fatum przekroczeń będzie narzędziem przyczyniającym się do ochrony pracowników na stanowiskach pracy. Artykuł przedstawia zastosowanie algorytmów rozpoznawania wzorców (takich jak klasyfikator Bayesowski, czy algorytm k-Nearest Neighbors) dla sygnałów EKG w celu określenia, czy ochotnik został poddany działaniu pola magnetycznego. Rozpatrywany jest dwuklasowy problem klasyfikacji nadzorowanej. W pierwszym etapie klasyfikator jest uczony na podstawie ciągu uczącego, zawierającego sygnały EKG zarejestrowane przed (klasa 1) i po (klasa 2) godzinnej ekspozycji ochotnika na pole magnetyczne. W etapie drugim nauczony klasyfikator sam decyduje o wyborze klasy dla nowego sygnału EKG. Porównanie wyników klasyfikacji ze znanym rzeczywistym faktem narażenia lub brakiem narażenia na pole magnetyczne pozwala wyznaczyć jakość klasyfikatora. Jakość klasyfikatora jest mierzona ryzykiem popełnienia przez klasyfikator błędu. Niska wartość ryzyka oznacza, że taki klasyfikator może być używany do detekcji wystąpienia narażenia na pole magnetyczne na podstawie analizy sygnału EKG.