Detection of local changes in resistance by means of data mining algorithms

Abstract. The following article presents results of examination of the resistance of the special electrodes made with using vacuum technology. These electrodes can be a item of clothing and can be used for electrical stimulation and monitoring of physiological parameters. The discussion of the discrepancies of e-fiber resistances is carried out by means of the concept of data mining with exceptions.

Materials and methods

In the previous papers [2,7] the process of applying conductive layers by thermal evaporation was also discussed. The deposition process was carried out after obtaining a generated initial vacuum of $10^{-7}$ bar and the application of the layer lasted 5 minutes. Silver with high purity 99.99% was used in the process of layer application.

One of the problems to be solved during process of making the pattern of electrode matrix is good electrical properties without interruption over the entire path length between the sensor and the interface of the data collector. In the preparation of electrodes on the surfaces of the textile the difficulty in adhesion to the substrate of the electrically conductive layer, as well as difficulties in obtaining continuous paths with good conductivity should be expected.

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Fig. 1. The image of created electrodes in the PVD process.
The four-point method of resistance measurement is based on indirect measurement of the resistance of the samples using electrodes, which are placed on the sample as it is presented in the figure 3.

Next, the resistance was obtained from the rule:

\[
R = \frac{1}{2} \left( \frac{U_{2-3}}{I_{1-4}} + \frac{U_{2-3}}{I_{4-1}} \right)
\]

where \(R\) – measured resistance, \(U\) - measured voltage drop between the pair of 2 and 3 electrodes, \(I\) - forced current between measuring electrodes i.e. 1 and 4 or 4 and 1.

Because of the nature of the study authors did not take into account the adjustments associated with the edge effect recommended in the Polish standard for the method of surface resistance calculating. [8]

In the research local variations in resistance were observed. They result from the layout of the fibers in the fabric, the parameters of the evaporation process and the method of preparing the surface for PVD. Because the resistance of particular electrode is very important parameter in the process of gathering data the analysis of the distribution of resistance is a crucial in the designing of wearable sensors.

Another technological problem to be solved is the connection of the prepared electrodes with the signal supply lines to the data recording device. The thickness of resulting layers is about 20 nm and they have a low mechanical strength. Unfortunately, the attempts which have been made to connect the electrodes were failed. Further research will be carried out with the unique merger techniques using microwelding laser [9]. However, some another problems connected to the technological process can occur inter alia oxidation layers as well as the formation of intermetallic compounds [10].

The quality of the conductive layer and the constant resistance value over the entire surface of the formed electrode affects the amount of errors and distortions in the transmitted signals.
Identification of the exceptions in the collected data

The development of information technologies including image analysis [11,12], algorithms for the detection of exceptions [13] in pre-defined databases, contribute to the development of not only the procedures for the processing of sensitive data such as banking, but also, medical diagnosis [14-16].

This article focuses on using data mining algorithms that detect exceptions in data sets. Data mining is a complex process that uses a very large range of algorithms for classification, clustering, detecting all kinds of exceptions and outliers, or detecting dependencies between data. It is obvious to search the new methods to support the detection of exceptions. Detecting outliers as a research problem encompasses a wide spectrum of applied techniques, primarily due to the variety of the denied tasks and purposes of the system. The outliers have many causes: because of natural human error, measurement device errors, natural error in population, changes in the functioning of systems or faults in the system, criminal activity of people, etc.

The tests are based on k-neighborn, DBSCAN and CLARANS algorithms to detect the local resistance changes.

One of the simplest classification methods is the k-nearest neighbor algorithm. It is based on a simple principle, namely: “data model belongs to this class, to which belong most of its k neighboring models”. Therefore, the classification of a model means designating k samples from the training data set, located the closest in the context of the used metric (e.g. Euclidean distance, Manhattan or Hamming distance). Next, the class to which the analyzed sample of data belongs is determined. Here one of the two methods is used:

Majority Voting – method of voting on equal rights – the sample belongs to the class, to which belong most of k neighbors

Inverse Distance Voting – method of voting taking into consideration distance – for each of the classes among the found k neighbors the sum of inverse distances from the analyzed sample is calculated. This sample is classified to this given class, for which the calculated sum is the biggest.

The Density Based Spatial Clustering of Applications with Noise – DBSCAN algorithm is the most popular algorithm belonging to the group of algorithms based on density [2]. The disadvantage of partitioning algorithms, that is, the difficulty in detecting spherical clusters, was solved by the introduction of algorithms based on density. In the developed methods clusters are the areas that are characterized by big density of objects.

This algorithm requires two input parameters:

- E - defines the maximum radius of neighborhood for a given object, all objects being in this area are called “neighbors”;
- MinP is the minimum number of points required to form a cluster, a point is called the core point, if in the neighborhood of the given point there are at least MinP points.

Another type of algorithm is CLARANS (Clustering Large Applications Based on Randomized Search), which is a combination of PAM (Partitioning Around Medoids) and CLARA (Clustering for Large Applications). It searches the graph randomly to and points located centrally in the group.

It requires the following initial parameters:

- Maxneighbor - the maximum number of neighbors of the node to be checked.
- numlocal - the maximum number of local minima information on which can be gathered

• numberofclasses - the number of classes which are considered as possible
• minimum the number of local minima for consideration before the end of the algorithm.

CLARANS (Clustering Large Applications Based on Randomized Search), belongs to the group of partitioning algorithms which use a limited search strategy. It is based on a random graph searching to find medoids representing the group.

In this conducted study it was assumed that there are three incorrect resistances which can be detected and treated as exceptions. One is the resistance of above 80 [m\(\Omega\) / square], which can occur as the temperature increases. Another is the fact that for R [m\(\Omega\) / square] > 100 m\(\Omega\) / square means total destruction of the electrode. The third exception is the resistance above the value of R [m\(\Omega\) / square] > 33 m\(\Omega\)/square. In the analyzed set seven exceptions were introduced.

Three exceptions related to the first group of resistance of above 80 [m\(\Omega\) / square] and two exception for the two other groups of exceptions. The density DBSCAN algorithm was the most effective, although the k-NN also classified correctly. CLARANS had trouble finding a real local minimum. Grouping is only possible if all the objects are in operational memory. This is the cause of a significant reduction of the size of the test file. DBSCAN algorithm and k-NN analyzed and detected exceptions quickly and with high accuracy. With proper selection of input parameters they detected other extreme values.

In order to reduce the cost of testing in a real environment, a part of it will be conducted using the COMSOL simulation environment software that allows simulation of even very complex processes [18, 19]. It is also possible to use neural networks [20] or the parallel algorithms [21] to optimize the calculating of the resistance value.

Summary:

The paper provides a brief description of the methods for detecting exceptions with particular emphasis on studied algorithms and most of all the preliminary results of experiments related to detecting exceptions defined as a resistance change in the electrodes produced by PVD method on flexible surfaces.

The study shows that there is a possibility of making electrodes with a surface resistance of single m\(\Omega\)/square by PVD method on a flexible textile substrates. It should be remembered that the mechanical washing process may cause local deterioration of the electrical properties of the sensors. [17]

The fact that the resistance value is constant on the entire surface of the produced electrode is very important. This determines the levels of errors and interference minimizing during signal transmission. Proper quality of transmission lines and electrodes has a direct impact on the correct detection of exceptions analyzed by the diagnostic system. In the process of the application of the sensors it is very important to recognize the difference between resistance value recognized by the diagnostic system as the correct one and the resulting one from the on-line measurements. According to the authors a carried out comparative analysis using the DBSCAN algorithm is the most effective for this purpose.

Due to the very high complexity of the analysis of the received signals the possibility of using neural networks should be considered in future work. They are used in the optimization of complex processes e.g. [20,21].
Currently, studies on the identification of exceptions were conducted for three generated files. This was done in order to make a preliminary comparison of these algorithms and test the feasibility of the operation of each of them on the prepared sets. The next steps will address real samples.

The authors hope that these studies will help identify the regularities in obtained values but most of all disorders resulting from local changes in the resistance of parameters of deposition process and the way of preparation of the substrate. In the longer term, research will focus on the detection of sensory life functions using modern method of monitoring e-fibers described in this article.

LITERATURE


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