Development of a personal identification technique for automation systems

V A Chastikova, S A Zherlitsyn and Y I Volya
Department of Computer Technologies and Information Security, Kuban State Technological University, Krasnodar, 350072, Russia

E-mail: chastikova_va@mail.ru

Abstract. The given article considers the development of a personal identification technique based on the mechanism of scanning and analyzing such biometric parameter as a vein pattern of the palm for automation access control systems. A number of problems characteristic of the existing approaches to solving the given problem have been formulated and the operation analysis of the main ones has been carried out. A mechanism for reading a vein pattern of the palm, as well as three methods for further analysis of the referred biometrics and personal identification: a method based on a categorical classification, a method based on a binary classification, and a combined method have been developed. The resulting architecture of the neural network for the categorical classification of the vein pattern has been built and a method for calculating the number of the model parameters depending on the number of the registered subjects has been obtained. Based on the results of the research, experimental measurements of the system operation accuracy have been made while implementing the mentioned methods. The system based on a binary classification has demonstrated the highest accuracy; however applying a combined approach allows improving the obtained result.

1. Introduction
Access control and management systems based on identification mechanisms are one of the most important and immediate directions in the development of automation systems.

Despite their simplicity and ease of use, the basic identification factors, such as keys and password information have a number of disadvantages, including the possibility of disclosure, forgery, password mining and loss. The use of biometric information minimizes the risk of the previously mentioned threats [1].

The identification mechanism is quite often a crucial component of the system and it is highly relied on. Among the latest trends in the development of authentication mechanisms, one cannot ignore the increased demand for methods that use the biometric characteristics of the subject [2,3].

The purpose of the given work is to develop a technique for identifying a person by the vein pattern of the palm, based on the neural network means.

The hardware and software complex, which allows performing personal identification based on the given biometric identifier, has been implemented on the basis of the developed technique.

2. Relevance
Considering the current level of modern technologies development, information systems have become crucial components of almost any kind of activity. Unrestricted access of unauthorized persons to some
of them can lead not only to huge economic costs, but in some cases to man-made disasters. The main method of dealing with such threats is the introduction of identification systems, as well as access control [4].

3. Formulation the problem
Currently the set of technologies used for identification by the vein pattern of the palm is mainly based on two key methods - the graph method and the one based on calculating the distance between the analyzed and registered images by means of various metrics.

Graph method. It is based on the comparison of the topology of veins. There are many different implementations, but the generalized algorithm consists of the following steps:

- obtaining an image of a palm with veins;
- pre-processing for noise reduction and vein identification;
- construction of lines corresponding to the identified veins;
- converting a set of lines into a weighted or ordinary graph;
- comparison of lengths and weights of the corresponding edges, the angles between the edges at the nodes, topological similarity.

The given algorithm has to refer to a set of identification samples at each execution of the identification procedure, which does not allow isolating the identification system from the storage of biometric personal data.

Another disadvantage of the algorithm is the need to compare the provided sample with each of the samples registered in the system, which is an extremely resource-intensive process considering a growing number of identification subjects.

Among other disadvantages of the referred method it is important to mention the following: extremely high dependence on the quality of lighting, the angle and bend of the palm, image and background noise, general instability of work [5].

Method based on distance calculation. It is based on calculating the distance between the analyzed and registered images applying various metrics, such as cosine distance, Euclidean distance, and others. Scaling and image rotation are also often used in conjunction with this method. Such measures increase operation stability of the algorithm, but they multiply its complexity and resource intensity. Thus, the given method retains the main disadvantages of the previous one – high computational complexity during operation and the impossibility to separate the identification system and storage of biometric personal data.

The implementation of the identification process based on classification applying neural networks is intended to compensate for the previously mentioned disadvantages of existing approaches.

4. Imaging
The task of personal identification systems is to match the subject of identification with his identifier, which uniquely identifies this subject in the information system. Depending on the organization, the identification system can determine the appropriate access subject or verify belonging of the same identifier to the intended subject based on the provided identifier [6].

The personal identification system by the vein pattern of the palm analyzes the image obtained from a digital camera susceptible to infrared light. When a human hand (namely, a palm) is in the frame while it is being illuminated by near-infrared light, a pattern of veins, vessels and capillaries under the skin becomes noticeable in the image obtained from the camera.

The images obtained in this way, however, highly depend on the quality of the backlight and do not always have the proper degree of contrast. Nevertheless, this drawback can be eliminated if automatic post-processing is applied. An example of the resulting image is shown in figure 1.
Each image is stored in black and white form because the color components do not provide useful information about the examined veins.

The given study suggests several options for implementing the identification system based on the vein pattern of the palm applying neural network means.

5. Categorical classification
The first option is based on a categorical classification. To pass the identification, a provided sample is tested whether it belongs to a specific class from the set [7].

Figure 1. Example of a raw image of the palm veins.

Figure 2. Graphs of accuracy and loss changes during categorical classification training.

Figure 3. Graphs of accuracy and loss changes during binary classification training.
Thus, the neural network is trained to match each sample of the training set to the corresponding strictly predetermined class. In this case, the output of the neural network, when it is provided with one separate sample, will be the vector of the probability distribution of the given sample belonging to all classes known to the neural network. To minimize the number of errors of second kind, it is also reasonable to introduce a threshold value of probability for personal identification [8]. This value is determined empirically in the course of experiments with a given specific set of identification subjects.

Within the framework of the research, the described approach has been put into practice: a training sample has been collected and a neural network model has been built and trained.

For the approach, based on a categorical classification, the best accuracy value in the experimental series was 0.9149. The graphs of accuracy and loss changes during training for test and validation subsamples are shown in figure 2.

6. Binary classification

The second option is based on the principle of a binary classification. In this case, the task of the neural network is to analyze the belonging of the shown identifier to only one strictly defined subject. The output of the neural network in this situation is two values - the probability of a match and the probability of a mismatch. It is also necessary for the considered method to apply a threshold value to confirm a match [9].

In the case of categorical classification, there is only one single neural network in the system, which is responsible for checking the match of each access subject to his identification record. To add a new user to the system, it will be necessary to retrain the last layers of the neural network.

In the case of a binary classification, each access subject has his corresponding lightweight neural network, which quickly learns and checks the accuracy of the user’s matching to the identification record in the system. In this case, the user must either point to the requested identification record explicitly, or use an additional identification factor, or the system must linearly check the correspondence of the received image with each identification record. All of these options have their pros and cons, and the choice of the ultimate algorithm depends on the way this mechanism is used.

The described approach has been also implemented applying the same training set and computational base.

For the approach, based on a binary classification, the accuracy reached the value of 0.9789. The graphs of accuracy and loss changes during training for test and validation subsamples are shown in figure 3.

7. Combined method

There is also a third option for the application of the described methods - a combined, two-stage one. In order to increase the reliability of the system and minimize the number of errors of the second kind, identification is performed according to the first method, and then according to the second one, but this time it is carried out for the known access identifier determined at the first stage.

8. Conclusion

On the basis of the developed hardware-software complex for personal identification by means of a vein pattern of the palm, researches of the proposed technique have been carried out.

The resulting neural network architecture for solving the categorical classification tasks is shown in table 1. The value of n is equal to the number of subjects, registered in the system, and can vary from 2 to 100 in the tested configurations; however, it can be changed to the higher side.

| Name of the layer (layer type)                      | Output vector dimension | Number of parameters |
|----------------------------------------------------|-------------------------|----------------------|
| conv2d_1 (input layer)                             | (1274, 714, 64)         | 3200                 |
| max_pooling2d_1 (subsampling layer)                | (637, 357, 64)          | 0                    |

Table 1. Neural network architecture.
| Layer Type           | Output (Kernel Size, Stride, Output Dimension) | Parameters |
|---------------------|---------------------------------------------|------------|
| conv2d_2            | (635, 355, 128)                             | 73856      |
| max_pooling2d_2     | (317, 177, 128)                             | 0          |
| conv2d_3            | (315, 175, 128)                             | 147584     |
| max_pooling2d_3     | (157, 87, 128)                              | 0          |
| conv2d_4            | (155, 85, 128)                              | 147584     |
| max_pooling2d_4     | (77, 42, 128)                               | 0          |
| flatten_1           | (413952)                                    | 0          |
| Dropout             | (413952)                                    | 0          |
| Dense_1             | n                                          | 26492992   |
| Dense_2             | n                                          | 65 * n     |

Thus, the developed neural network contains 12 layers and from 26,865,346 to 26,871,716 parameters. The interval of the number of parameters is determined by the permissible number of the registered subjects - from 2 to 100. Since each subject has his corresponding output of the neural network, each additional one will add 65 new weights to the model.

The presented architecture is the most resource-intensive of all used in each of the technique implementations, which makes it possible to give an upper estimate of the computational complexity of the system as a whole.

Application of multi-category classification using neural networks for the distribution of identifiers among users registered in the system exceeds in terms of computational complexity one verification check by means of any classical methods, but it is less resource-intensive than checking a match to each of the registered subjects, which is carried out by means of the known methods.

The proposed technique has shown the results sufficient for being used in an automation access control system.

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