ELEKTROTEHNIŠKI VESTNIK 91(5): 284-289, 2024
ORIGINAL SCIENTIFIC PAPER

Person Gait Recognition as a Part of the Intelligent Security System

Adnan Ramakić[1], Zlatko Bundalo[2], Dušanka Bundalo[3]

[1] *Technical Faculty, University of Bihać, Bihać, Bosnia and Herzegovina*
[2] *Faculty of Electrical Engineering, University of Banja Luka, Banja Luka, Bosnia and Herzegovina*
[3] *Faculty of Philosophy, University of Banja Luka, Banja Luka, Bosnia and Herzegovina*

E-mail: zlatbun2007@gmail.com

Abstract. The ways and possibilities of implementing a person gait recognition method in an intelligent security system intended for collective residential and office buildings, as well as for houses, are considered and described. The person gait recognition method is based on the patterns of human walking, i.e. on the way of walking. It is an interesting method for identification purposes requiring no interaction with the person to be identified, i.e. the identification process is performed silently, without disturbing the person. Since artificial intelligence is inevitable today in many areas of the human life, the approach proposed in the paper is based on deep learning. A deep learning model is developed, analyzed and tested. The obtained results are presented. A well-known gait recognition method called the Gait Energy Image (GEI) is used. As the gait dataset, the Casia Dataset B is used.

Keywords: Person Gait Recognition, Intelligent Security System, Deep Learning, Gait Energy Image (GEI)

Prepoznavanje hoje osebe kot del inteligentnega varnostnega sistema

V prispevku so obravnavani in opisani načini in možnosti implementacije metode prepoznavanja hoje osebe v inteligentni varnostni sistem, namenjen skupnim stanovanjskim in poslovnim objektom ter hišam. Prepoznavanje človekove hoje je metoda, ki temelji na vzorcih človekove hoje, torej temelji na načinu hoje. Je uporabna metoda za namene identifikacije, saj ne zahteva interakcije z osebo, da bi jo identificirali. Ker je umetna inteligenca danes neizogibna na številnih področjih človeškega življenja, pristop, predlagan v tem prispevku, temelji na globokem učenju. V ta namen smo razvili, analizirali in testirali model globokega učenja. Za osnovo smo uporabili metodo Gait Energy Image (GEI). Kot nabor podatkov o hoji smo uporabili nabor podatkov Casia B.

1 INTRODUCTION

The use of technology in connection with security systems is unavoidable. In recent decades, technology has advanced in many areas of the human life. For this reason, collective residential buildings, office buildings, houses and other types of objects use technology for the implementation of some types of security systems. The type of the security system depends on the needs of the user and can be implemented in different ways. The use of a security system is more necessary in some cases than in others. For example, a security system is more necessary in office buildings where businesses that handle sensitive data are located than in common residential buildings. Also, access to certain areas in businesses is restricted and only some employees have access. The use of security systems in homes depends on the owner of the home, and depending on that, a security system may or may not be implemented.

The paper deals with the use of human gait recognition in a security system. The main focus of the paper is to investigate the use of the method in an intelligent security system. The purpose of gait recognition in such intelligent security system is primarily to identify the person in order to gain access to the building, to certain areas of the building and to the elevator(s) in the building. Gait recognition is a method based on the patterns of human walking. In other words, it is based on the way of walking. It is an interesting method for identification purposes as it does not require interaction with the person to be identified. This means that an identification process can be carried out silently without disturbing the person. In contrast to gait recognition, for example, identification based on fingerprints or handprints (palms) requires interaction with the person, as the person must place a finger or palm on the corresponding device in order to be identified.

In addition to gait recognition, face recognition is also an interesting method for the use. In the past, face recognition methods required interaction with the person to be identified, but today, with advanced technology, this type of the method can be performed without interaction with the person. With the great advances in artificial intelligence in recent years, these types of the

Received 10 September 2024
Accepted 14 November 2024

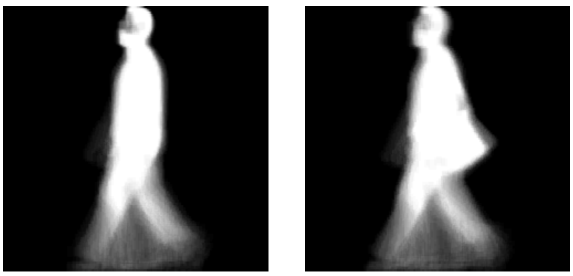
methods, such as gait recognition and face recognition, are usually realized through machine learning or deep learning. The paper presents an approach of deep learning combined with the method of gait recognition to realize an example of an intelligent security system. Accordingly, a deep learning model for identifying persons based on their gait is developed, analyzed and described.

The paper is organized as follows. After the introductory section, Section 2 describes an example of an intelligent security system and the use of gait recognition. Section 3 presents the architecture of the presented model for gait recognition, the defined settings and the dataset. Section 4 gives the results related to the model and dataset. Section 5 shows conclusions.

2 INTELLIGENT SECURITY SYSTEM

A security system can be based on different technologies and can use different approaches. Nowadays, artificial intelligence is developing rapidly and can be used in security systems. Since the approaches of machine learning and deep learning are frequently used today, an intelligent security system can be realized with some of the mentioned approaches. The paper describes an intelligent security system based on deep learning and the method of gait recognition. A deep learning model is developed, implemented and used to identify a certain person based on his/her gait.

The deep learning model for gait recognition is used to access a specific building, regardless of whether it is a collective residential building, an office building or a house. The well-known Gait Energy Image (GEI) [1] is used as a method for gait recognition. Essentially, GEI is an image that contains the silhouettes of a person during a gait cycle. These silhouettes are normalized, aligned and temporally averaged to obtain a GEI image [1]. Some examples of the GEI images are shown in Figure 1. The examples are taken from the Casia Dataset B [2][3][4]. Some other method of gait recognition can also be used instead of GEI. Some interesting elements and other approaches to gait recognition can be found in [5 - 18].



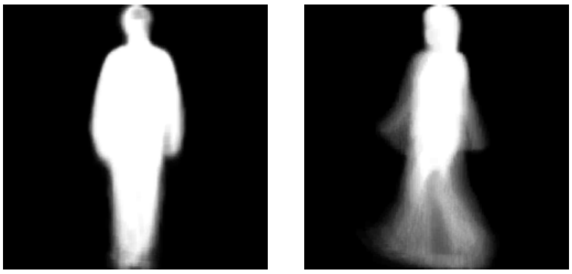


Figure 1. Examples of the GEI images [2][3][4].

Certain hardware elements are required to implement an intelligent security system. First of all, one or more servers are needed to host everything related to the intelligent security system. Some cloud solutions can also be used instead. Multiple RGB (Red, Green, Blue) cameras are also used for surveillance, i.e. for detecting and tracking persons. Cameras with different ranges can be used. The RGB-D sensors (Red, Green, Blue – Depth) can also be used if gait recognition method uses depth images instead of or together with the RGB images. In this case, the gait recognition method uses the RGB images for identification, so it is sufficient to use only the RGB cameras. It should be noted that the hardware requirements are not considered and analysed in our work.

Generally speaking, an identification system can be roughly divided into two parts, the identification part and the database part, i.e. the dataset creation part. The images for each person are captured and stored (image acquisition) in the database creation part. On the other hand, a new image of a particular person is captured and compared with the images stored in the database in the identification part. In addition, the features can be extracted from the images and used accordingly in the identification process.

As mentioned above, the artificial intelligence is developing rapidly and an identification system may be realized using machine and deep learning approaches. Various tools and platforms are available for the development of the machine or deep learning models, and the realization of an intelligent security system based on artificial intelligence is easier and more accessible. In this context, a specific model should be developed to identify persons and a specific database should be created containing images for each person. The database is intended for the training and validation process of the model. An example of an office building with an intelligent security system is shown in Figure 2. It shows how an intelligent security system looks and is implemented in an office building.

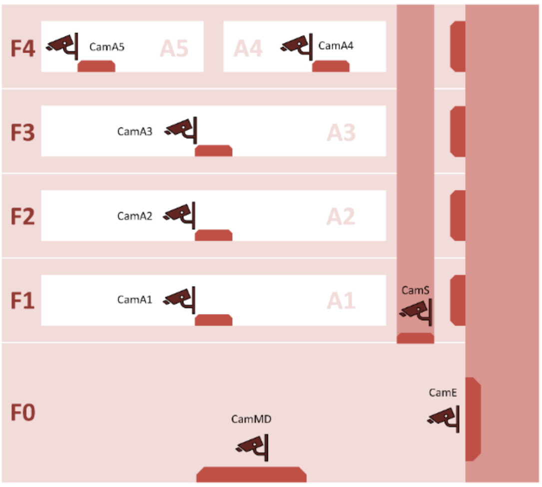


Figure 2. Office building with an implemented intelligent security system.

The building in Figure 2 has a ground floor (labeled *F0*) and four floors (labeled *F1*, *F2*, *F3* and *F4*). It is equipped with eight cameras (*CamMD*, *CamE*, *CamS*, *CamA1*, *CamA2*, *CamA3*, *CamA4* and *CamA5*) designated to detect and track persons and capture images for each person. As mentioned above, everything related to the intelligent security system should be hosted on one or more servers (cloud solutions can be used instead).

Most importantly, a deep learning model should be implemented, trained and validated on the images of the persons having access to the building. With the eight cameras, the images of a certain person are captured and a new GEI image of the person is created and passed to the model to gain access to a specific area of the building. To gain access to a building, a person to enter it is detected with *CamMD* positioned at the main entrance. Images are captured during a gait cycle of the person.

Figure 3. Identification method based on the deep learning approach and GEI.

Afterwards, the silhouettes of the person are extracted and a GEI image is created. It is then passed to the implemented deep learning model. Figure 3 shows the process of the person identification based on the gait recognition method (GEI) and the deep learning approach.

As to the main entrance and *CamMD*, the door at the main entrance is unlocked after the person has been positively identified and the person can enter the building. Besides *CamMD* positioned at the main entrance, there are seven other cameras. The *CamE* camera is located at the elevator and after the person has been identified, the person can enter the elevator. The *CamS* camera is positioned at the main staircase and after the person is positively identified, the door is unlocked and the person can enter the staircase. The cameras *CamA1*, *CamA2*, *CamA3*, *CamA4* and *CamA5* are located in front of the individual areas in the building. As can be seen in Figure 2, there are five areas (sectors) in the building, labeled *A1* to *A5*, and only certain people have access, e.g. to area *A1*. The same rule applies to all other areas.

An intelligent security system can also be used in residential buildings, which means that it is not exclusively intended for use in office buildings. An example of a collective residential building with implemented intelligent security system is shown in Figure 4.

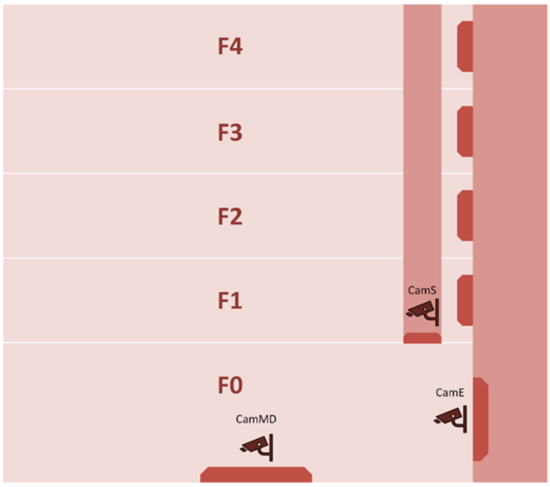


Figure 4. Example of a collective residential building with an implemented intelligent security system.

The collective residential building shown in Figure 4 has a ground floor (*F0*) and four floors (*F1*, *F2*, *F3* and *F4*). The building is equipped with three cameras *CamMD*, *CamE* and *CamS*. They are used to detect and track persons and capture images of each person, as in case of the office building. As there are no specific areas in the building, there are only three cameras compared to the eight used in the office building. In the case of a collective residential or an office building, certain hardware elements are used to implement an intelligent security system. This means that one or more servers (or cloud solutions) are also used to host everything related to the intelligent security system. In this case, *CamMD*, *CamE* and *CamS* have the same task as in the previous example and are located at the main entrance, elevator and staircase.

When a person enters the building, the elevator or the staircase must be positively identified. In the case of the elevator, a positively identified person enters the elevator and the elevator transports the person to the floor where the person's apartment is located. The intelligent security system should be configured also to bypass the elevator if the person needs to go to another floor. In other words, there should be an option that allows the person to independently choose any floor within the building.

In both above cases, the certainty of the identification of a particular person must be above 90%. If the gait recognition fails, the intelligent security system implements another identification method as a backup (e.g. face recognition, fingerprint or some kind of identification card). The method of face recognition is also considered in our work. A deep learning model for face recognition is developed for this purpose.

3 Model Architecture, Settings and Datasets Used

For the gait recognition method, a deep learning model is developed using the TensorFlow [19] platform together with Keras [20]. More specifically, the Keras Sequential model is used. The model consists of a preprocessing layer, convolution layers, pooling layers, reshaping layer and core layers. The Casia Dataset B [2][3][4] is used as the gait dataset. It is a well-known dataset containing the images of 124 persons. The persons' images are taken from 11 views and they have a normal gait, clothing and carrying condition changes. Besides the silhouette images, the GEI images are also available in the dataset.

A total of 56 persons are randomly selected from the Casia Dataset B and are used for the training and validation process of the developed model. Three sets of the GEI images are used. This means that for each person, images corresponding to the *side view*, *frontal view* and *back view* of the persons are used. To achieve this, the GEI images with the angles of 72, 90 and 108 degrees are used for the side view. In the case of the frontal view, the GEI images from the Casia dataset B are taken at the angles of 0, 18 and 36 degrees. Finally, for the GEI images of the back view, the angles of 144, 162 and 180 degrees are used. For all the used GEI images and angles, all conditions such as a normal gait, clothing and carrying condition changes are taken into account. The used GEI images are shown in Figure 5. The first row shows the GEI images corresponding to the side view, the second row shows the GEI images corresponding to the frontal view and the third row shows the GEI images corresponding to the back view.

A total of 1680 GEI images are used for the first set (side view), 30 images for each person. For the second set (frontal view), 1680 GEI images are also used. Again, 30 GEI images are used for each of the 56 persons. In the third case (back view), 1672 GEI images are used. The majority of the 56 persons contain 30 images, but in several cases the number of the images is several images less. The reason for this is the unavailability of several images for some angles. In the training and validation process, the images are split so that 80 percent of them are used for training and 20 percent for validation. This means that in the case of the first set (side view), 1344 GEI images are used for training and 336 images for validation. In the second case, i.e. the second set (frontal view), the numbers are the same. For the third set (back view), 1338 GEI images are used for training and 334 images for validation. Other training settings include 20 epochs and the Adaptive Moment Estimation Optimizer (Adam) [21] is used.

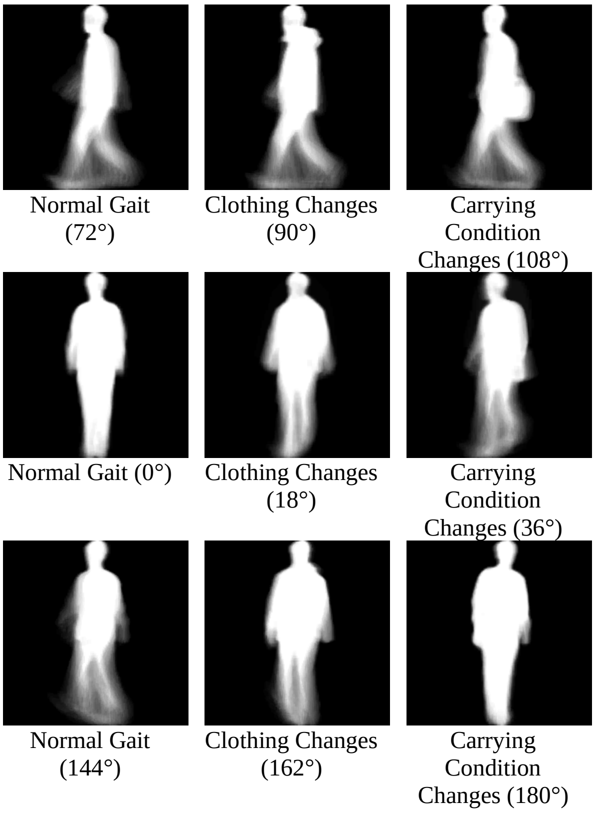


Figure 5. Examples of the GEI images (Casia Dataset B [2][3][4]) used for the training and validation process of the developed model.

As mentioned above, a backup method should also be implemented. In our case, a deep learning model for face recognition is also developed for this purpose. The TensorFlow platform and Keras (the Keras Sequential model) are also used. The model of face recognition is similar to the model of gait recognition. It consists of a preprocessing layer, convolution layers, pooling layers, reshaping layer, core layers and regularization layer. *The Facial Images: Faces95* [22] dataset is used to train and validate the model. The dataset consists of face images of

72 persons with a resolution of 180 x 200. The background is a red curtain. A total of 56 persons are randomly selected and used as in the case of the Casia Dataset B. A total of 1120 face images are used, 20 images for each person.

In the training and validation process, the images are split as for the GEI images, 80 percent of them are used for training and 20 percent for validation (896 face images for training and 224 face images for validation). The data augmentation is also performed to increase the diversity of the training set. Other settings are as in the previous case, 20 epochs and the Adaptive Moment Estimation Optimizer (Adam) are used.

4 Results and Discussion

In the development of our deep learning model for gait recognition, the following results are obtained in terms of the validation accuracy. For the first set (side view), the validation accuracy is 99.40%. For the GEI images corresponding to the frontal view (second set), the validation accuracy is 97.32%. For the third set (back view), the validation accuracy is 98.80%. The results for the three GEI image sets are shown in Figure 6 and Table 1.

Table 1. Validation accuracy of the developed model.

The set of the GEI images	**Casia Dataset B**	**Validation Accuracy**
The first set (side view)	Viewing angle of 72, 90 and 108 degrees	99.40%
The second set (frontal view)	Viewing angle of 0, 18 and 36 degrees	97.32%
The third set (back view)	Viewing angle of 144, 162 and 180 degrees	98.80%

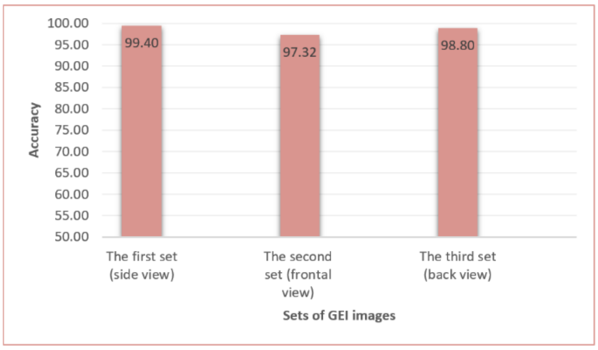


Figure 6. Validation accuracy of the developed model.

As seen in Table 1 and Figure 6, the developed model achieves promising results in terms of the validation accuracy for each of the GEI image sets. The results obtained are above 97% in each case, which means that the approach is interesting and promising for the use in different security systems.

Figure 7 shows the training and validation accuracy for each of the three cases, i.e. for the three GEI image sets. The left part of Figure 7 shows the results for the first set (side view), the middle part shows the results for the second set (frontal view) and the right part shows the results for the third set (back view) of the GEI images.

The results achieved with the backup method for face recognition are also promising. For the defined settings and the dataset used, the validation accuracy is over 90%. This makes the face recognition method suitable for the use in different security systems. It should be noted that different face recognition methods are widely used today.

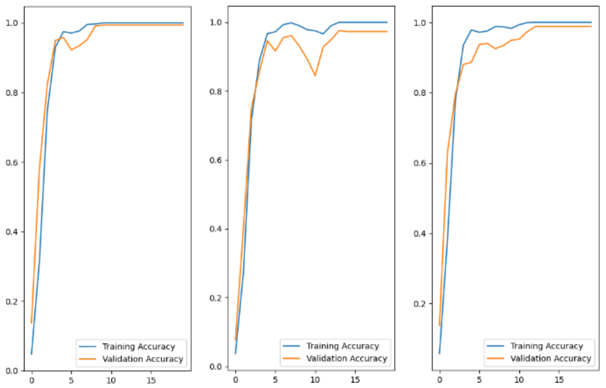


Figure 7. Training and validation accuracy of the developed model and used set of the GEI images.

It can be concluded that gait recognition is interesting and promising for the use in various security systems. The main advantage of gait recognition is that it requires no interaction with the person to be identified. Moreover, the person can be identified from a long distance. This means that the person can go through an identification process without being disturbed and without knowing that the identification process is in progress. A disadvantage of the gait recognition method is that it requires several steps, which means that it takes much time and consequently the implementation can be challenging. The GEI method can also be used as an example. The images are captured during a gait cycle, the silhouette images are then extracted and the GEI images are created at the end. The method is difficult to implement as the process takes a lot of time. Other methods of gait recognition have similar problems. This can be alleviated to a certain extent by using the state-of-the-art hardware.

Face recognition is considered an interesting alternative or support to gait recognition for not requiring as many steps as other methods. Furthermore, with the today's hardware and modern cameras, face recognition can be implemented with no interaction with the person to be identified. This means that face recognition can be also suitable for the identification tasks at a greater distance.

In our future work it would be interesting to investigate some other gait recognition methods, specifically focusing on maximization of the speed of identification and simplification of the implementation. The identification accuracies should also be analyzed and compared.

5 CONCLUSION

The paper analyses the possibility of using person gait recognition in intelligent security systems i.e., the way and possibilities of implementing a method of gait recognition in an intelligent security system for collective residential buildings and office buildings as well as for houses. Gait recognition is an interesting method for identifying persons, as it usually requires no interaction with the person to be identified. It is suitable for identification purposes from a greater distance, which can be of interest in many areas. Nowadays, artificial intelligence is in a great momentum, so these methods are usually based on machine and deep learning approaches.

The paper presents a deep learning model intended for person identification based on gait. The model is developed using the TensorFlow platform together with Keras, i.e. the Keras Sequential model. The Gait Energy Image (GEI) is used as the method for gait recognition. Casia Dataset B is used for the model training and validation process. The validation accuracy results are promising and are above 97% for the used settings and GEI images. This means that gait recognition can be used in security systems. A separate deep learning model is also developed for face recognition to serve as a backup method for identification. The validation accuracy results are also promising, they are above 90% for the used settings and the dataset.

In our future research, we should analyze some other methods of gait recognition using less steps than GEI during the identification process. An effort will be taken to maximize the speed of identification and to simplify the implementation compared to other gait recognition methods.

REFERENCES

[1] Han, J. and Bhanu, B., "Individual Recognition Using Gait Energy Image", IEEE Transactions on Pattern Analysis and Machine Intelligence, 28(2), 316-322, IEEE, 2005.

[2] Yu, S., Tan, D. and Tan, T., "A Framework for Evaluating the Effect of View Angle, Clothing and Carrying Condition on Gait Recognition", In: 18th International Conference on Pattern Recognition (ICPR), 441-444, IEEE, 2006.

[3] Zheng, S., Zhang, J., Huang, K., He, R. and Tan, T., "Robust View Transformation Model for Gait Recognition", In: 18th International Conference on Image Processing, 2073-2076, IEEE, 2011.

[4] Official Web Page of the Institute of Automation, Chinese Academy of Sciences,
http://www.cbsr.ia.ac.cn/english/Gait%20Databases.asp (25.03.2024).

[5] Ramakić, A. and Bundalo, Z., "Gait Recognition as an Approach for People Identification", In: International Symposium on Innovative and Interdisciplinary Applications of Advanced Technologies, 717-726, Springer, 2022.

[6] Arora, P. and Srivastava, S., "Gait Recognition Using Gait Gaussian Image", In: 2nd International Conference on Signal Processing and Integrated Networks (SPIN), 791-794. IEEE, 2015.

[7] Bashir, K., Xiang, T. and Gong, S., "Gait Recognition Using Gait Entropy Image", 2009.

[8] Chattopadhyay, P., Roy, A., Sural, S. and Mukhopadhyay, J., "Pose Depth Volume Extraction from RGB-D Streams for Frontal Gait Recognition", Journal of Visual Communication and Image Representation, 25(1), 53-63, Elsevier, 2014.

[9] Hofmann, M., Bachmann, S. and Rigoll, G., "2.5D Gait Biometrics Using the Depth Gradient Histogram Energy Image" In: 5th International Conference on Biometrics: Theory, Applications and Systems (BTAS), 399-403, IEEE, 2012.

[10] Iwashita, Y., Uchino, K. and Kurazume, R., "Gait-based Person Identification Robust to Changes in Appearance", Sensors, 13(6), 7884-7901, MDPI, 2013.

[11] Kumar, M. N. and Babu, R. V., "Human Gait Recognition Using Depth Camera: A Covariance Based Approach", In: Proceedings of the 8th Indian Conference on Computer Vision, Graphics and Image Processing, 1-6, 2012.

[12] Preis, J., Kessel, M., Werner, M. and Linnhoff-Popien, C., "Gait Recognition with Kinect", In: 1st International Workshop on Kinect in Pervasive Computing, 1-4, New Castle, UK, 2012.

[13] Ramakić, A., Bundalo, D. and Bundalo, Z., "An Approach to Gait Recognition Using Deep Neural Network", Acta Technica Corviniensis-Bulletin of Engineering, 16(2), 1-6, 2023.

[14] Ramakić, A., Bundalo, Z. and Bundalo, D., "A Method for Human Gait Recognition from Video Streams Using Silhouette, Height and Step Length", Journal of Circuits, Systems and Computers, 29(7), 2050101, World Scientific, 2020.

[15] Ramakić, A., Sušanj, D., Lenac, K. and Bundalo, Z., "Depth-Based Real-time Gait Recognition", Journal of Circuits, Systems and Computers, 29(16), 2050266, World Scientific, 2020.

[16] Lenac, K., Sušanj, D., Ramakić, A. and Pinčić, D., "Extending Appearance Based Gait Recognition with Depth Data", Applied Sciences, 9(24), 5529, MDPI, 2019.

[17] Sivapalan, S., Chen, D., Denman, S., Sridharan, S. and Fookes, C., "Gait Energy Volumes and Frontal Gait Recognition Using Depth Images", In: International Joint Conference on Biometrics (IJCB), 1-6, IEEE, 2011.

[18] Sivapalan, S., Chen, D., Denman, S., Sridharan, S. and Fookes, C., "The Backfilled GEI-A Cross-capture Modality Gait Feature for Frontal and Side-view Gait Recognition", In: International Conference on Digital Image Computing Techniques and Applications (DICTA), 1-8, IEEE, 2012.

[19] TensorFlow, https://www.tensorflow.org (13. 08. 2024).

[20] Keras, https://keras.io (13. 08. 2024).

[21] Kingma, D. P. and Ba, J., "Adam: A Method for Stochastic Optimization", arXiv preprint arXiv:1412.6980, 2014.

[22] Libor Spacek's Facial Images Databases,
https://cmp.felk.cvut.cz/~spacelib/faces (12.03.2024).

Dr. Adnan Ramakić received his PhD degree in Electrical Engineering from the Faculty of Engineering, University of Rijeka, in 2021. He is currently an assistant professor at the Technical Faculty, University of Bihać. His research interests include image processing, machine and deep learning, and computer security.

Dr. Zlatko Bundalo received his PhD degree in Electrical Engineering, from the Faculty of Electrical Engineering, University of Banja Luka, in 1989. He is currently a full professor at the same faculty (retired). His research interests include electronics, electronic systems, computer sciences, embedded systems, information systems and security.

Dr. Dušanka Bundalo received her PhD degree in Electrical Engineering from the Faculty of Electrical Engineering, University of Banja Luka, in 2006. She is currently a full professor at the Faculty of Philosophy of the same university. Her research interests include computer sciences, embedded systems, information systems and security.