Normalization of Vehicle License Plate Images Based on Analyzing of Its Specific Features for Improving the Quality Recognition

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Abstract: This paper presents technique for recognizing license plates structured characters of the Republic of Kazakhstan. This technique includes methods for converting the geometric-topological characteristics of license plates and the method for classifying alphanumeric characters by using cluster analysis. Developed modified algorithm for character recognition based on methods of contour analysis and template method with the addition of proposed transformations.

Keywords: image processing; geometric-topological characteristics; contour analysis; character segmentation; character recognition

Introduction

Nowadays there are a lot of recognition systems for license plates of vehicles, that are characterized by rapid response time and high recognition rate even if automobiles move at high speed. However, in order to provide continuous up and running of such systems, special expensive hardware is required. To purchase the equipment of this type is not always reasonable in case vehicles speed is not high. This relates to gasoline service stations, parking areas, storefronts, internal development roads and garage co-ops, etc. The demand for researches and development of such technologies for solving problems of this level made it necessary to develop methods and models adopted both for detection of special structures on an image and for analysis of structured symbols for identification of text information reflected on registered license plates.

Generally, methodologies [1-5] used for the development of license plates recognition systems can vary due to different conditions of their operation and peculiarities of the national numbering system. However, on the one hand, most such recognition systems have acommon structure that realizes standard information technology. The technology, as a rule, consists of the following steps: image generation, image preprocessing, object localization, image segmentation, and recognition. On the other hand, at present there are some methods of image characteristic points detection – points (areas) that possess high local information content [6-10]. Such points of interest for many methods are stable enough to photometric and geometric image distortions including irregular brightness variations, shift, angling, scale conversion, view distortion. The initial stage of recognition task is selecting of characteristic points on an image. Main advantage of characteristic points used for such tasks is relative simplicity and rate of their identification. Besides, sometimes it isn't always possible to distinguish other characteristic features (sharp outlines or areas), as for characteristic points they can be identified in the vast majority of cases. As a consequence, it is possible to replace stages of image formation and preprocessing for object localization with the method of object area detection used according to characteristic points, and only after that to provide steps for identification by the common geometric and morphological methods, knowing the information about the object structure.

1 Problem Formulation

The goal of the work is to study the provided stages of data conversion for the realization of the informational system of license plate recognition in the Republic of Kazakhstan (RK). The information technology includes basic stages: localization, preprocessing of the localized object, segmentation, and recognition. Localization is a very challenging stage in the task of license plate recognition. A license plate by itself is rather informative due to sufficient visibility of the information provided on it. Generally, inverse colors are used for characters and backgrounds. As for a vehicle and surrounding changing background they are rather many-coloured and vary due to brightness variations, shifts, angling, scale conversion, and view distortions. Methods of image characteristic points detection are suggested for these very conditions: SIFT [11, 12], Speeded-Up Robust Features (SURF) [11, 13], Histogram of Oriented Gradients (HOG) [14, 15], Local Binary Patterns (LBP) [16] and others.

In order to locate vehicle license plates the authors have suggested to use the contour analysis method that enables to define the shape of the image entirely. It also contains all the required information for their identification according to the shape. Such an approach enables not considering internal points of an image and thus reducing the amount of processed information. As a consequence, it can facilitate the work of the system in real-time mode.

Contour implies a number of pixels that separate the object from the background. Freeman Chain Code will be taken as the method of coding contours that are applied for the representation of boundaries. They are represented by the sequence of straight lines segments of different lengths and directions. 4- and 8-side grid is the basis of this representation. The length of every segment is determined by the resolution of the grid, and directions are set by the selected code. In order to represent all the directions in 4-side grid, 2 bits is enough, bur 3 bits is required for 8-side grid of chain code.

Such an approach enables moving from two-dimensional objects to their one dimensional (vector) description, i.e. development of chain code can be considered the procedure of image vectorization.

The most evident method of getting contours from an image is the Canny edge detector [17]. Any methods of binary image acquisition can be taken for this use: threshold transformation, object selection according to colour, Canny algorithm applies 4 filters for detecting horizontal, vertical, diagonal lines, as lines can be in different directions on an image. It results in a binary image containing lines. When the localized license plate is preprocessed, it is converted as a single line. License plates specific feature is that they are of different formats (single-line or two-line) and they have areas of different colours. So it is more convenient to convert them to the standard one-line type of the same grey colour for further processing. Character's recognition is the final stage in the procedure of license

plate recognition. For this purpose, the images containing license plate symbol generated in the result of preprocessing and segmentation are analyzed on the basis of number plate topological features.

2 License Plate Localization

Contour analysis approximates the data in the image to simple geometric shapes. Thus, this method allows filtering the obtained contours by the signs of the ratio of sides, area, perimeter, angle, etc.

The general sequence of actions of the algorithm is as follows: the input of the algorithm comes pre-processed image. Then, it is checked for binarization of the image. Using the binarized image, contours are selected on the image.

To find the contour of the license plate it is necessary to filter all found contours by criteria reflecting the characteristics of the license plate in comparison with other objects of the world. According to the scheme of the algorithm of contour analysis for the localization of license plates should be filtered by the following characteristics of the contour:

- in form, i.e. the contour should contain only 4 vertices, pairwise-parallel opposite sides and angles between adjacent vectors close to 90°, and also have a length in relation to the width, satisfying the values of proportions;

- by size, i.e. the contour must meet the requirements of the minimum and maximum area of the content area in order to be able to extract data (symbol images) of sufficient information (sufficient size).

As a result, the algorithm highlights with a red border all areas in which the license plate can be placed.

In case of full compliance, the circuit is added to the list of detected license plates of the vehicle.

2.1 License Plate Preprocessing

Preprocessing includes methods of license plates geometric and topological characteristics transformation. It is required for the conversion of license plates of all types to standard single-line type of the same grey colour.

According to RK license plate standards [18-20] license plates of the Republic of Kazakhstan differ significantly from each other both in size (520x112 mm, 280x202 mm, 240x202 mm, 288x202 mm, 260x242 mm), and in the number of lines (single-line, two-line). In order to transform two-line number plates into a standardized single-line type, the following algorithm is provided in Figure 1.

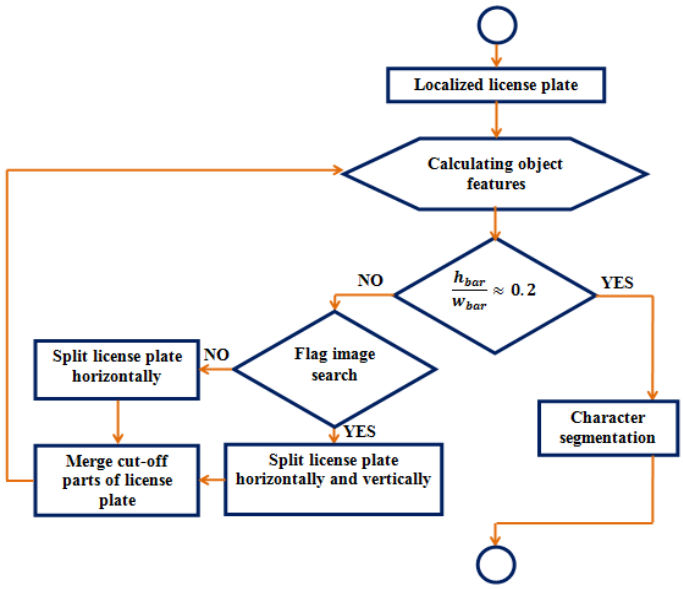


Figure 1
The transformation algorithm two-line case to a one-line license plate

When a number plate localization is finished, the characteristics of the found objects are additionally estimated. These operations are required for the conversion of two-line license plates into one-line license plates. A license plate filling ratio (1) and aspect ratio (2) are taken as permanent characteristics.

$$Z_{coef} = \frac{S_{obj}}{h_{bar} * w_{bar}}, \tag{1}$$

$$Z_{AspRat} = \frac{h_{bar}}{w_{bar}}. \tag{2}$$

where $\mathbf{S_{obj}}$ - the area of the found object, $\mathbf{h_{bar}}$ – the height of a license plate, $\mathbf{w_{bar}}$ – the width of a license plate.

The value $\mathbf{Z_{coef}}$ for a license plate will be equal to the number known in advance as the value of aspect ratio $\mathbf{Z_{AspRat}}$ is constant. Thus, the number of an object of interest (a license plate) is defined, basing on the value $\mathbf{Z_{coef}}$. It has been found out that aspect ratio value $\mathbf{Z_{AspRat}}$ for single-line license plates is 0.2. If the value of aspect ratio is higher or lower than 0.2, it means that the localized object is a two-line license plate. In order a license plate could be converted into single-line type, first, it is necessary to define what standard it belongs to, as they have considerable differences in the structure and appearance. The Republic of Kazakhstan flag image in the upper left corner of a number plate of 2012 serves as the distinguishing feature.

In order to find the left edge of the flag, the algorithm of changing a number plate colour from blue to white is used. In case flag image is found, a number plate is considered to be a standard license plate of 2012. Further on the algorithm goes to the next cutting stage. In this case, the cutting stage consists of two sub-stages: horizontal cutting in half (see Figure 2(a)-I) and vertical cutting of the second cut part in half (see Figure 2(a)-II). Thus cutting results in the dividing of a two-line license plate into 3 parts (see Figure 2(b)). Figure 2 from (a) to (b) shows the result of the described stage.

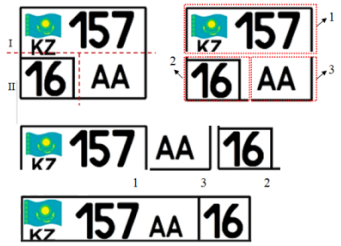


Figure 2

License plate split stages. (a) Split sub-stages: I - upper part and II – lower part (b) Result of split sub-stages: 1, 2, 3

After the cutting stage, the cut parts of a license plate are joined in accordance with the established procedure, and its result is provided in Figure 3.

Figure 3

Merge of license plate. (a) Merge of circumcised parts: 1, 2, 3. (b) Result of merge

If the flag image is not found, this number plate type is considered a standard license plate of 2003, so only horizontal cutting in half algorithm is applied. Further on the cut parts of a license plate are joined in accordance with the established procedure.

Thus, all the types of two-line license plates are converted into single-line license plate type. Some results are provided in Table1.

The conducted transformations resulted in conversion of the two-line license plates into a single-line license plate type, their colours are as follows: black characters on a white background, white characters on a red background, white characters on a blue background, black characters on a yellow background, blue characters on a white background.

Table1

Results of transformation two-line license plate to a single-line form

Standard	Input two-line license plate	Transformed one-line license plate
2012y		
2003y		

In order to convert a license plate image into the same grey colour, colours of a license plate are converted according to the algorithm provided in Figure 4.

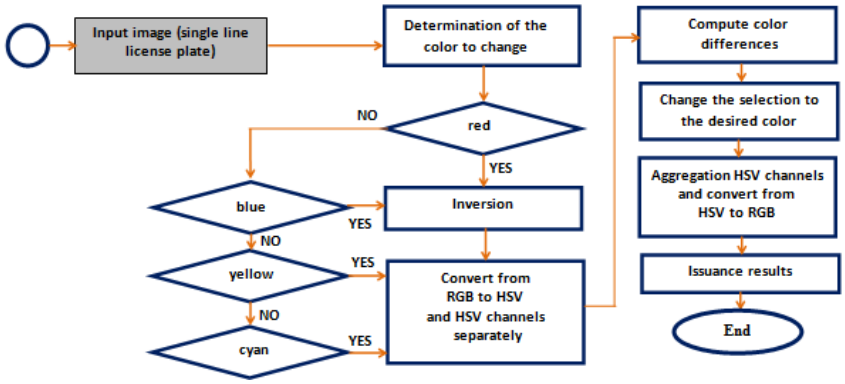


Figure 4

The scheme of the algorithm for background and alphanumeric characters colours conversion to produce images in the same grey colour

Before all the required conversions are carried out, image pixels intensity is normalized. The method suggested in the resource is used for normalization of all image pixels intensity. The given method resulted in the same weight of red, green, blue pixels. It can be explained by the following - while taking snapshots of the plane field, the light going through the recording system was absolutely white and the pixels sensitivity to different spectral regions was similar.

According to the suggested algorithm, the process of defining background colour starts for change. If the background is red or blue, these images undergo inversion that results in the value that is inverse to the original value. While an image is inverted, the value of all pixels in channels are converted into opposites according to the scale of 256 colours.

Then RGB system is converted into HSV. Representing colour model HSV (Hue, Saturation, Value) is more sensitive to color distinction than RGB model, so it describes colours nearly as well as a human does. The results of license plates colours normalization and inversion are provided in Table 2.

Table 2

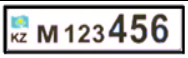
The results of license plates colours normalization and inversion

Transformed one-line license plate	One-line license plate after inversion
	
	

The procedure includes image conversion from RGB model into HSV model and breakdown into H, S, V channels, i.e. 4 images are created: one is for storing and the other three for further segmenting of an image into separate channels H, S, V. After that difference between colours is calculated and the current colour is replaced with the required colour. Next, channels H, S, and V are combined and color space is converted from HSV into RGB. Thus, all colourful license plates are converted into number plates with a white background. The results of background and alpha-numeric character's colours conversion are provided in Table 3.

Table 3

The results of background and alphanumeric characters colours conversion

Transformed single-line license plate	Transformed single-line license plate in the homogeneous palette of gray
	
	
	
	

Thus, the suggested conversion method enables converting of all types of license plates into the single standard one-line type of the same grey colour.

3 Segmentation of a License Plate

In case this method is used for solving the problem of vehicle license plate segmentation, the task is to find outlines on the input image and to evaluate them according to the specified criteria. The area of the ruling box and aspect ratio are these criteria. Then, the found outlines are sorted in the order license plate reading. Character image is selected for every outline basing on the ruling box (see Figure 5).

Figure 5
Example of segmented characters

The produced images of characters are scaled to common size. The obtained character images are scaled to the total size of 34x44 and transferred to the output. It should be noted that the disadvantage of this approach is that this algorithm can't retrieve the required outlines under conditions of noise pollution and when low resolution images are processed.

4 Clustering Characters

As a rule, any object or image subjected to recognition and classification possesses a range of distinctive qualities and features [21]. According to RK license plate standards every character is characterized by the following feature vector: height (h) and width (w).

Preprocessing procedure based on feature vector enabled to take aspect ratios as a distinctive feature as they are invariable in relation to different conversions and deformations.

The size of numerals and letters on license plates differ in their height and width. If the height of numeric characters is 58 mm, their width is 30 and 33 mm, if their height is 70 mm, the width is 35 mm and 40.5 mm, if the height of numeric characters is 76 mm, their width is 38 mm and 44 mm. If the height of literal characters is 58 mm, their width is 39 mm, 43 mm, 44 mm, if their height is 76 mm, the width is 51 mm, 57 mm, and 58 mm. Examples of numeric characters are shown in Figure 6.

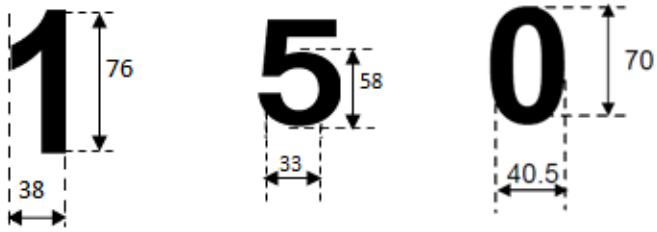


Figure 6
Dimensions of numeric characters «1», «5» and «0»

According to the evaluation of numeric and literal characters aspect ratio, clusters of characters and their single-valued characteristics are clearly defined. This statement validity is evaluated by an agglomerative hierarchical algorithm where the distance between objects is calculated with Euclidean distance, the distance between clusters is calculated using the nearest-neighbor principle [22]. A set of numeric and literal symbols is divided into 4 clusters by calculating sequentially all the required distances, by combining objects into clusters in accordance with the suggested algorithms, and as a result of clusterization.

Thus, the following conclusions can be made on each group of clusters

1) Ratio values of the first cluster is ranged between 1.31 and 1.35. the objects of the first cluster are the following literal characters: A, C, D, H, M, N, O, T, U, V, W, X, Y, Z.

2) The ratio values of the second cluster is 1.49. The objects of the second cluster are the other 8 literal characters: B, E, F, K, L, P, R, S. Besides the only ratio of the letter "W" is 1.31, the ratio of other letters varies from 1.33 to 1.35. It should be also noted that for letters of this cluster that are 76 mm high, the ratio is 1.33, and for those ones 58 mm high the ratio is 1.35 mm. It means that the license plate character's height parameter is also a characteristic feature for classification. It is significant to note that when literal character's height is fixed (58 or 76 mm), the height-to-width ratio is also fixed (1.33mm and 1.35mm respectively). As for the letter "W", in case it is 58 mm high, its height-to-width ratio is 1.32.

3) Ratio values of the third cluster vary from 1.93 to 2, its object is numeral 1.

4) Ratio values of the fourth cluster vary from 1.73 to 1.76. It is significant to note that when numerical characters height is fixed (58, 70 or 76 mm), height-to-width ratio is also fixed (1.73 mm – for the first and the third case and 1.93 mm for the second case). The objects of this cluster are the following numbers: 0, 2, 3, 4, 5, 6, 7, 8, 9.

Alphanumeric characters ratio values rendering is represented in Figure 7.

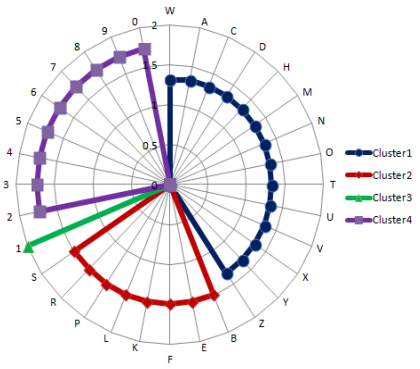


Figure 7
Clustering of alphanumeric characters

The conducted analysis of literal and numerical characters applied on license plates enabled to divide a set of alphanumeric characters into clusters which further are used for development of an effective classifying program.

4.1 Character Recognition

Before recognition stage belonging of a current symbol x to one of the clusters A_i,i=1,4 is defined. It has been established that after cluster analysis alphanumeric characters were divided into 4 clusters, where 2 clusters are clusters of literal characters, and the other two are the clusters of numerical characters. Belonging of a current symbol x to one of the clusters A_i,i=1,4 is defined by calculating the characteristic feature of this symbol and by comparing it with the average vector A_i,i=1,4.

Thus, the classifying program calculates the aspect ratio of the current symbol, which is invariant value and then compares it with the average value of each cluster. The classifying program refers symbol x to cluster Ai if height-to-width aspect ratio is 1.33; symbol **x** is referred to cluster A_2, if height-to-width aspect ratio is 1.49; symbol **x** belongs to cluster A_3 if height-to-width aspect ratio is 2; and finally symbol **x** is referred to cluster A_4, if height-to-width aspect ratio is 1.73. Then, a symbol is recognized by the method of simple patterns, when Hamming distance is used as image similarity measure.

On the basis of experimental research, it has been found out that the given approach reduces dimensions of selected characters considerably due to pre-determined clusters and enables to achieve iterates decrease thus providing characters processing speeding up.

In order to test the suggested information technology, the software program of characters recognition has been implemented. Computer vision library OpenCV (Open Source Computer Vision Library) was used for prototype realization [23].

Both static images and video sequences were used as the initial data of the system.

Two bases of templates were formed for algorithm running. The base of numeric characters templates is represented by 150 pattern images of characters. When templates were developed, the font was used that complies with RK standards. The base of literal characters templates consists of 330 images. Thus, 15 pattern images with different inclination angles have been selected for every character. This method has been tested on 7923 images of number plates, numeric characters recognition probability is 96.8%, literal characters recognition probability is 95.1%. Average recognition probability is 96%.

Conclusion

Information technology for RK license plates recognition is described in the given paper. HOG method is suggested for localization of license plates on an image.

This method is rather stable to photometric and geometric image distortions that include brightness variations, shift, angling, scale conversion, view distortion.

Geometric and topological characteristics of RK license plates have been studied in order to define service and symbolic-numeric information that is further used in development of characters recognition algorithms.

Analysis of geometric and topological characteristics of vehicles license plates in accordance with RK standards resulted in defining of basic characteristic features of license plates characters that are invariant relating to any conversions.

Methods of vehicles license plates geometric and topological characteristics conversion have been developed. They are based on conversion of license plates to standard single-line view and generating colourful number plates in the same grey colour.

The results of experimental research has proven that preliminary transformations considerably influence the images classification results. Conversion of all license plates to one type enabled reducing the time period for image processing.

Pilot information technology suggested in the given paper has provided rather consistent results of recognition - 96%.

The suggested methodology can be used not only for license plates of the Republic of Kazakhstan, but also for those ones of other countries.

References

[1] Björklund T., Fiandrotti A., Annarumma M., Francini G., Magli E. Robust license plate recognition using neural networks trained on synthetic images, Pattern Recognition, 2019, 93, 134-146

[2] Puranic A., Deepak K. T., Umadevi V. Vehicle Number Plate Recognition System: A Literature Review and Implementation using Template Matching, International Journal of Computer Applications, 2016, 134(1), 12-16

[3] Bharath B. P., Mahalakshmi S. Automatic license plate detection using deep learning techniques, International Journal of Scientific Research Today, 2017, 5(1), 107-112

[4] Rizvi S. T. H., Patti D., Bjorklund T., Cabodi G, Francini G. Deep classifiers-based license plate detection, localization and Recognition on GPU-Powered Mobile Platform, Future Internet, 2017, http://www.mdpi.com/1999-5903/9/4/66 (01.02.2018)

[5] Tlebaldinova A, Denissova N, Kassymkhanova D. Application of a scenario approach in development of a recognition system of vehicle identification numbers. In: IEEE 2015 6th International Conference on Modeling, Simulation and Applied optimization; Istanbul, Turkey; 2015, pp. 1-4

[6] Medjahed S. A. A comparative study of feature extraction methods in images classification, I. J. Image, Graphics and Signal Processing, 2015, 3, 16-23

[7] Zhang G., Ma Z., Niu L., Zhang C. Modified Fourier descriptor for shape feature extraction, Journal of Central South University, 2012, 19(2), 488-495

[8] Mullen R. J., Monekosso D. N., Remagnino P. Ant algorithms for image feature extraction, Expert Systems with Applications, 2013, 40(11), 4315-4332

[9] Dwivedi U., Rajput P., Sharma M. K. License Plate Recognition System for Moving Vehicles Using Laplacian Edge Detector and Feature Extraction, 2017, 4(3), 407-412

[10] He S., Yang C., Pan J-S. The Research of Chinese License Plates Recognition Based on CNN and Length_Feature, Proceedings of International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems (2-4 August 2016, Morioka, Japan), Trends in Applied Knowledge-Based Systems and Data Science, 2016, 389-397

[11] Panchal P. M, Panchal S. R., Shah S. K. A Comparison of SIFT and SURF, International Journal of Innovative Research in Computer and Communication Engineering, 2013, 1(2), 323-327

[12] M. Guzel, A Hybrid Feature Extractor using Fast Hessian Detector and SIFT, Technologies, 2015, 3(2), 103-110

[13] Hongbo Li, Ming Qi, Yu Wu A Real-Time Registration Method Of Augmented Reality Based On Surf And Optical Flow, Journal Of Theoretical And Applied Information Technology, 2012, 42(2), 281-286

[14] Dalal N., Triggs B. Histograms of Oriented Gradients for Human Detection, In CVPR, 2005, 886-893

[15] Prates R. F., Cámara-Chávez G., Schwartz William R., Menotti D. Brazilian License Plate Detection Using Histogram of Oriented Gradients and Sliding Windows, International Journal of Computer Science & Information Technology (IJCSIT), 2013, 5(6), 39-52

[16] Rahim Md. A., Hossain Md. N., Wahis T., Azam Md. Sh. Face Recognition using Local Binary Patterns (LBP), Global Journal of Computer Science and Technology Graphics & Vision, 2013, 13(4)

[17] J. Canny. A computational approach to edge detection. IEEE Transactions on Pattern Analysis and Machine Intelligence, 8(6):679{698, November 1986.- ĐĐ. 679-698

[18] ST RK 986-2003 - Road transport. State registration number plates with a retroreflective surface for motor vehicles and their trailers. Technical specifications

[19] ST RK 1176-2010 - State registration plates with a light-reflecting coating for separate types of vehicles and trailers. Specification

[20] ST RK 986-2012 - Road vehicles. State registration licence plates of retroreflective surface for motor vehicles and their trailers, and blank plates. Specification

[21] E. Rafajlowicz, "Data Structures for Pattern and Image Recognition to Quality Control" Acta Polytechnica Hungarica, Vol. 15, No. 4, pp. 233-262, 2018

[22] Ozaki R., Hamasuna Y., Endo Y. Agglomerative Hierarchical Clustering Based on Local Optimization for Cluster Validity Measures, Proceedings of IEEE International Conference on Systems, Man, and Cybernetics (SMC), (5-8 October 2017, Banff, Canada), 2017, 1822-1827

[23] Z. Balogh, M. Magdin, G. Molnar "Motion Detection and Face Recognition using Raspberry Pi, as a Part of the Internet of Things" Acta Polytechnica Hungarica, Vol. 16, No. 3, pp. 167-185, 2019