Załącznik 3

Autoreferat w języku angielskim

Summary of academic achievements

1. Name and surname: **Karolina Olga Nurzyńska**

2. Diplomas and scientific degree:

   a) **Ph.D. in Computer Science**
   Faculty of Automatic Control, Electrinics and Computer Science, Silesian University of Technology, Ph.D. thesis: "Method for creating multiresolution, deformable surfaces and its interactive visualization", supervisor: Prof. Ph.D., D.Sc. Eng. Konrad Wojciechowski, reviewers: Prof. Ph.D., D.Sc. Katarzyna Stąpor, Prof. Ph.D. D.Sc. Eng. Maria Pietruszka, 2009.

   b) **M.Sc. in Computer Science**
   Faculty of Automatic Control, Electrinics and Computer Science, Silesian University of Technology, M.Sc. thesis: "Database application for phone bills analysis", supervisor: Prof. Ph.D., D.Sc. Eng. Stanisław Kozielski, A with honors, 2005.

3. Information of the academic experience:

since 2013:	Assistant Professor, Institute of Informatics, Silesian University of Technology.
2012 – 2014:	Assistant Professor, Central Mining Institute.
2011 – 2013:	Postdoc Researcher, EkDan project, Institute of Informatics, Silesian University of Technology.
2011 – 2012:	Engineer, Central Mining Institute.
2009 – 2011:	Postdoctoral Fellow, Laboratory of Image Information Science Division of Electrical Engineering and Computer Science, Graduate School of Natural Science and Technology, Kanazawa University, Japan.
2005 – 2009:	Ph.D. student, Institute of Informatics, Silesian University of Technology.

4. Scientific achievement (according to the article 16, paragraph 2 of the Polish legal act dated on 14th March 2003, entitled Law on Academic Degrees and Title and Degrees and Title in the Arts):

   a) A series of thematically related articles, entitled: "Object recognition based on information contained in their external or internal form."

      I K. Nurzyńska, "Deep learning as a tool for automatic segmentation of corneal endothelium images", *Symmetry*, vol. 10, nr 3, pp. 60, 2018 /IF = 1,256; 30 pts of Polish Ministry of Science and Higher Education/

      II K. Nurzyńska, "Automatic segmentation of corneal endothelium images with convolutional neural network", in *Beyond Databases, Architectures and Structures. Facing the Challenges of Data Proliferation and Growing Variety*, S. Kozielski et al., Eds., pp. 323–333, vol. 928, Springer International Publishing Switzerland, 2018. /Web of

Science 15 pts of Polish Ministry of Science and Higher Education/

III K. Nurzyńska, A. Piórkowski, "The correlation analysis of the shape parameters for endothelial image characterisation", *Journal of Image Analysis and Stereology*, vol. 35, nr 3, pp. 149, 2016 /IF = 1,135; 15 pts of Polish Ministry of Science and Higher Education/

IV K. Nurzyńska, B. Smołka, "Smile veracity recognition using LBP features for image sequence processing", in *2016 International Conference on Systems Informatics, Modelling and Simulation (SIMS)*, pp. 89–93, IEEE, 2016. /Web of Science, 15 pts of Polish Ministry of Science and Higher Education/

V K. Nurzyńska, B. Smołka, "Smiling and neutral facial display recognition with Local Binary Patterns operator", *Journal of Medical Imaging and Health Informatics*, vol. 5, nr 6, pp. 1–9, 2015 /IF = 0,877; 15 pts of Polish Ministry of Science and Higher Education/

VI K. Nurzyńska, B. Smołka, "PCA application in classification of smiling and neutral facial displays", in *Beyond Databases, Architectures and Structures*, S. Kozielski, D. Mrozek, P. Kasprowski, B. Małysiak-Mrozek, D. Kostrzewa, Eds., pp. 398–407, Springer International Publishing, 2015. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

VII B. Smołka, K. Nurzyńska, "Power LBP: A novel texture operator for smiling and neutral facial display classification", *Procedia Computer Science*, vol. 51, pp. 1555–1564, 2015 /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

VIII K. Nurzyńska, M. Kubo, K. Muramoto, "Texture operator for snow particle classification into snowflake and graupel", *Atmospheric Research*, vol. 118, pp. 121–132, 2012 /IF = 2,2; 25 pts of Polish Ministry of Science and Higher Education/

IX K. Nurzyńska, M. Kubo, K. Muramoto, "Shape parameters for automatic classification of snow particles into snowflake and graupel", *Meteorological Applications*, vol. 20, nr 3, pp. 257–265, 2013 /IF = 1,518; 25 pts of Polish Ministry of Science and Higher Education/

X K. Nurzyńska, M. Kubo, K. Muramoto, "2D feature space for snow particle classification into snowflake and graupel", *IEICE Transactions on Information and System*, vol. E93-D, nr 12, pp. 3344–3351, 2010 /IF = 0,411; 13 pts of Polish Ministry of Science and Higher Education/

b) Elaboration on the scientific goal of the enlisted articles and achieved results, along with their potential applications.

4.B 1. Introduction

The presented series of publications concerns the use of the description of the external and internal form of objects, reflecting the information contained in the shape

Table 1: Zestawienie prac składających się na cykl publikacji.

		Rok wydania	Udział (%)	IF	Punkty MNiSW	Liczba cytowań WoS*	Google**	Scopus***
(1)	[I]	2018	100	1,256	30	0	1 (1)	—
	[III]	2016	80	1,135	20	6 (4)	7 (5)	6 (5)
	[V]	2015	80	0,877	15	2 (0)	4 (2)	—
	[VIII]	2012	90	2,200	25	4 (4)	10 (8)	8 (6)
	[IX]	2013	90	1,518	25	7 (4)	7 (4)	6 (4)
	[X]	2010	90	0,411	13	3 (2)	7 (6)	4 (3)
(2)	[II]	2018	100	—	15	0	0	0
	[IV]	2016	80	—	15	0	1 (1)	0
	[VI]	2015	80	—	10	4 (3)	5 (4)	4 (3)
	[VII]	2015	50	—	10	5 (3)	7 (5)	6 (4)

(1) — articles in JCR journals;
(2) — conference papers;
* — according to the Web of Science Core Collection (without self-citations in the brackets);
** — according to the Google Scholar (without self-citations in the brackets);
*** — according to the Scopus (without self-citations in the brackets).

and texture, for the analysis of digital images. Fitting the obtained measures to a specified problem is verified in the space of features or results from the analysis of information obtained at the output the of deep neural networks. The proposed methods have been used to recognize the type of snowfall, in the verification of the sincerity of a smile, and made it possible to describe the characteristics of the corneal endothelium, which is an example of their applicability in various fields. Although the subject and purpose of applying the developed methods cover a wide range of issues, in all the cases the classification of features acquired from images plays a major role – local features that reflect texture characteristics are extracted, the shape parameters of the objects being segmented are calculated and, most importantly, their integration is performed in order to create models accurately describing the chosen issue.

The habilitation achievement has been presented in the form of a series of 10 thematically related publications, whose bibliometric data are summarized in Table 1. The series consists of 6 articles in journals indexed in the Journal Citation Reports database (JCR) and 4 works indexed in the Web of Science. According to co-authors' statements, my percentage in multi-author publications was from 50% to 90%, two works are solely my authorship. Tables 1, 2 and 3 list selected bibliometric data for publications that make up the series and for all my publications. As it has been presented, the total IF is 14,15, and the number of points of the Polish Ministry of Science and Higher Education for all my post-doctoral publications is 495. These works were cited 66 times (43 times without self-citations), and the Hirsh index is 4. Taking into account the percentage participation of co-authors, the total weighted impact factor (IF) of listed works is 6,5817, and the number of points of the Polish Ministry of Science and Higher Education is 173. These works according to the Web of Science Core Collection were cited 31 times (22 times without self-citations).

The aforementioned areas of application of the developed solutions are presented

Table 2: Impact factor, according to JCR, for all my papers and those included in the series.

Publications	IF	
	total	weighted
Included into the series	7,397	6,5817
All	14,15	10,1018

Table 3: Selected bibliometric data of all the papers; retrived on January 29th, 2019 .

Database	Number of papers	Citations	Citations excluding self-citations	h-index
Web of Science Core Collection	34	66	43	4
Google Scholar	65	166	*ND*	7
Scopus	41	85	62	6

in the following paragraphs. In subsection 4.B.2, the scope of research regarding recognition of the morphological structure of snow is presented. The next part 4.B.3 discusses research related to the automatic analysis of the expression of emotions on the example of facial images presenting happiness. Then, in point 4.B.4, the scope of work on segmentation and description of the quality of the corneal endothelium is shown. In point 4.B.5, the most important original achievements described in the publications comprising the series presented are given. Then on page 25, there is a list of cited literature. References to publications from the series are marked with subsequent Roman numbers, e.g. [I], and references to the literature with the number of the bibliography, e.g. [1]. References to my post-doctoral publications which are not part of the series are preceded by the prefix "poz", e.g. [poz1]; a list of these publications can be found in point 5., where a description of other completed research works and information about participation in research and development projects is also provided.

4.B 2. Recognition of morphological structure of the snow

While working at Kanazawa University in Japan, I took part in the EMEA (Environmental monitoring in East Asia) project led by Prof. Ken-Ichiro Muramoto. One of the objectives of the research was to develop a method for determining and predicting the intensity of snowfall. The ability to predict the strength of snowfall would counteract local floods and mudslides that are common in the Kanazawa area due to the accumulation of factors responsible for cloud formation, such as topology of the terrain or wind system [21].

The determination of rainfall intensity (Z) on the basis of the radar beam reflectance (R) has been linked by Marshall and Gunn [33] in the relation

$$\mathrm{Z} = \mathrm{BR}^{\beta}, \tag{1}$$

where B and β are coefficients depending on the type of precipitation. In the case of rainfall, the determination of coefficients is not problematic due to the spherical shape of raindrops. However, for snowfall, the situation is much more complicated. The diverse three-dimensional structure of snowflakes makes it much harder to determine parameters unequivocally.

Snowfall in the region where the research was conducted is dominated by two types of snow. There are fewer graupels, whose petals are characterized by a compact structure resembling a miniature ball of snow with a diameter of up to 1 cm. In Poland, precipitation of this type of snow also happens, however, the petals are much smaller. The second type of snowfall is ordinary snowflakes, which can take on a variety of shapes, their consistency is often very loose, and the length can reach up to several centimetres.

4.B 2.1 Shape parameters in the morphological analysis of the snow

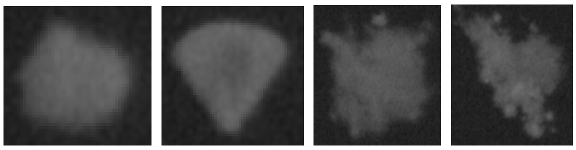
The most commonly recognized feature of snowflakes is their shape, hence the concept to develop a method that on the basis of this feature allows its automatic classification to one of the two considered classes (i.e. graupel, snowflake). Describing an object in an image using a shape is an issue known in the literature related to image analysis. The shape can be described using statistical features of the image, such as moments of various order [19], or their improved form insensitive to translation and rotation proposed by Hu [23]. From the other side, many mathematical formulas based on the contour of the object have been developed, which try to best reflect how round it is (e.g. shapeless, roughness, and circularity measures) or elongated (e.g. Feret, Malinowska measure) [24]. More advanced measures strive to describe the complexity of the shape by analyzing the relationship between the course of the contour and the centre of gravity (e.g. the measure of Danielsson, Haralick, Blair-Bliss).

The use of computer vision methods for the automatic morphological analysis of snow was an innovative approach, not previously implemented on such a scale. It required the commencement of tests from verification of the applicability of existing methods of shape description. In addition, in [IX], [X] a number of new measures were proposed, the aim of which was to describe the complex structure of the snowflake and at the same time create a characteristic that differentiates it in a clear way from the graupels. Below is a general description of the proposed method for describing the shape of snow particles (details can be found in the aforementioned publications):

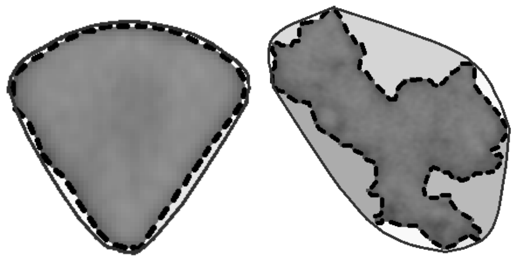
Flake number – from observing the data, it appeared that the graupels are observed individually in the pictures, while in the case of snowflakes there may be several of them. It is a result of their loose construction, which means that the object can be divided or connected during falling.

Concave number – determines the number of concave places in the object in relation to its convex hull. The idea of this measure is presented in Fig. 1(b).

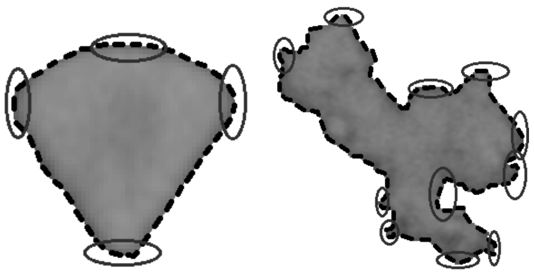
Corner number – analyzing the course of the contour, it can be seen that the number of bends depending on the type of snowflake is different, hence the number of significant contour bends was considered a measure, the concept



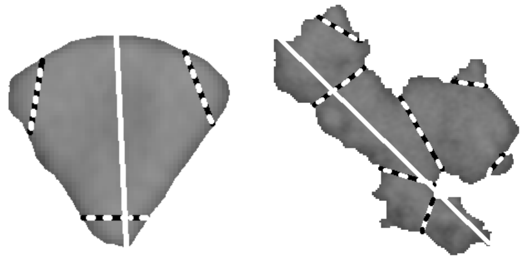
(a) Original images



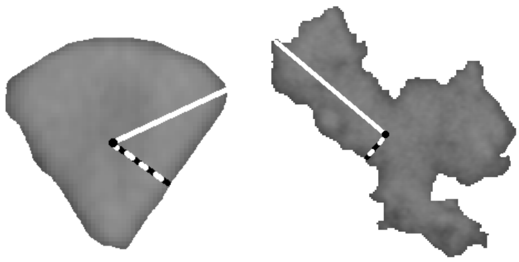
(b) Concave number



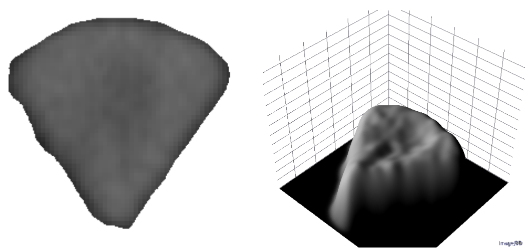
(c) Corner number



(d) Min-max distance



(e) Min-max centre distance



(f) Volume

Figure 1: Proposed measures describing the shape of a snowflake. On the left side a sample of grauple, on the right a snowflake. Source: [IX],[X].

of which is presented in Fig. 1(c), where selected bends on the contour are marked with ellipses.

Min-max distance is a measure describing the relationship between the longest (solid line) and the shortest (dashed line – shows several possible solutions) with a chord connecting two sides of the snowflake illustrated in Fig. 1(d).

Min-max centre distance describes the relationship between the pixel on the contour, which is the closest to the centre (dashed line) of the object's gravity and the one that is the furthest (solid line). Fig. 1(e) shows the idea of using this measure.

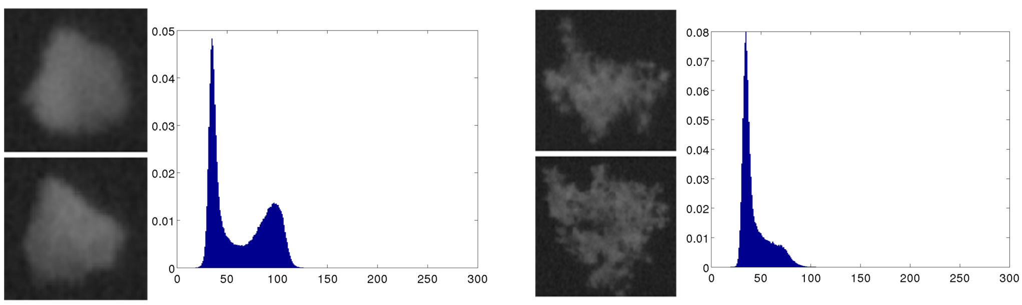
Volume interpreted on the basis of pixel brightness, the fact that parts of the object closer to the camera are more brightly lit than those further away is used, hence the snowflake image can be interpreted as a three-dimensional map of heights. Fig. 1(f) presents the visualization of this concept.

Most of the proposed methods for describing the shape depending on the type of snow turned out to be highly effective (over 98% of accuracy) in the identification of graupels, but they did not perform well with snowflakes (often their effectiveness dropped below 50%). However, the high quality of graupel detection allowed to propose cascading classification methodology in [X]. In the first step, methods dealing with the detection of graupels (one or more one after the other) were used to detect a small number of objects, but with very high efficiency (up to 99%). Objects that were not recognized at this stage went to the stage of classification using the k-nearest neighbours method (kNN) or a classifier based on the Mahalanobis minimum distance and the support vector machine (SVM) method described in the work [IX], whose vector features were built with the use of data from two methods of image description. As a result of experiments, the proposed **corner number** applied in the first stage, after which the kNN classifier based on **concavity number** and **volume** allowed to obtain the efficiency of 94%. In conclusion, the novel element of the work was not only to propose own measures of shape to the morphological description of the type of snow but the use of computer vision methods in climatology research.

4.B 2.2 Texture as a method for snow structure description

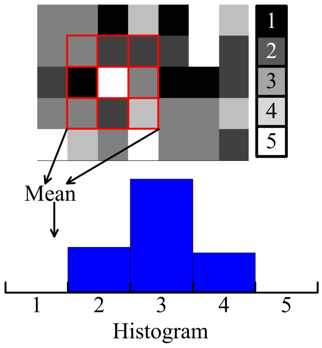
An alternative approach to describing objects representing snow was to analyse their texture. This approach was dictated by the fact that histograms (for all images from the database) presented in Fig. 2 for each type of snow differed significantly. In addition, description of the type of snow based on **brightness difference** defined as the largest difference in grey levels in a moving window with size 3×3 passing through the object gave good classification results (72–80%) using the cascading approach to classification discussed in the previous section, that is presented in the work [X].

Recognition of objects based on features describing their texture is a widely studied problem in the literature. The most frequently mentioned techniques include first order features (FOF), whose vector of features is based on a probability of occurrence of a given grey level described by a normalized histogram, from which the values of mean, variance, entropy, energy, kurtosis and skewness are calculated. Next, a second order method was developed to create a two-dimensional co-occurrence matrix (COM) of pairs of grey levels in the image [20, 46]. On its basis, 14 features describing the texture characteristics are calculated. The grey-tone difference matrix (GTDM) is built from the input image to reflect the manner in which human analyses the texture [3]. Similarly as in the previous methods, the features describ-

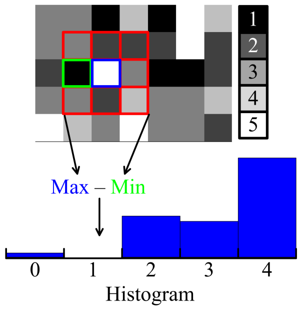


(a) Graupel (b) Snowflake

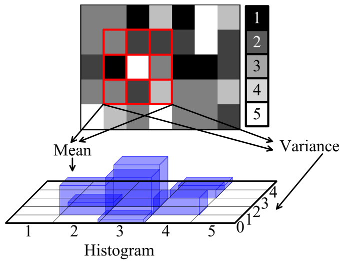
Figure 2: Average histogram of grey-scale levels recorded for both snowflake type. Source: [VIII].



(a) Mean histogram



(b) Min-max histogram



(c) Mean-variancehistogram

Figure 3: Proposed measures based on information contained in the image texture. The idea of the methods was presented for an image with five levels of grey. Source: [VIII].

ing the texture are calculated on its basis. Considering the observation that good textures are characterized by frequent changes in grey levels, while coarse textures accumulate pixels of the same value around each other, a run length matrix (RLM) was created that counts the length of pixels of the same shade [18], which also serves as the basis for calculating the features [2]. Another method of texture analysis was proposed by the authors of local binary patterns (LBP) [35, 36], who for each pixel based on its neighbourhood code the characteristics of the local texture, whereas the entire picture is described with a histogram of these features. In addition, they define a new measure of variance as the second dimension of the histogram describing textures. The above techniques have been used to recognize the type of snow, as described in the works [VIII], [poz21].

In addition, in work [VIII] three methods have been proposed that describe the texture, which are based on local statistics, calculated for a 7×7 moving window, which passes through the entire image:

Mean histogram – the feature vector is calculated as a histogram of the mean value (quantified to 64 levels of grey) calculated in a moving window. Fig. 3(a) presents the idea of this approach.

Min-max histogram (MMH) – a feature vector calculated as the absolute difference between the largest and smallest value in a moving window, as shown in Fig. 3(b). The length of the histogram has been set to 64 elements.

Mean-variance histogram (MVH) – two-dimensional histogram (with dimensions 16×16) co-occurring values of the mean and variance calculated in a moving window presented in Fig. 3(c).

On the other hand, it was decided to abandon the calculation of features based on histograms/matrices in the previously discussed methods available in the literature and it was proposed to use matrices as feature vectors given to the input of the classifier. Therefore, the following feature vectors were created:

$\mathrm{FOF_H}$ normalized histogram storing grey levels quantified up to 64 values.

$\mathrm{COM_M}$ co-occurrence matrix calculated for images in which grey levels have been quantified up to 16 values.

$GTDM_M$ grey level difference matrix calculated for the original image.

RLM_M a run length matrix for particular grey levels (taking into account the existence of 32 shades and a maximum length of 20 pixels).

The classification was carried out by kNN considering 25 neighbours when making decisions (the value of k was the optimal setting resulting from previous experiences). The best results for distinguishing individual types of snow were achieved for the COM_M method (86.06% efficiency), not much worse efficiency results because more than 85% was obtained for the other proposed techniques and for LBP. In the case of methods which calculate features from the matrix (FOF, COM, GTDM, RLM), the classification results were below 82%. In order to increase the efficiency of recognition between types of snow, it was proposed to create feature vectors based on data calculated from two methods describing the texture. As a result of such an approach, the best outcome of 87.89% was obtained for the vector of features built from LBP and $GTDM_M$. This, in turn, led to the elimination of redundant information in the vector of features from the previous experience using principal component analysis (PCA). The use of Karhunen-Loève transformations allowed to significantly shorten the feature vector and increase the classification efficiency to 100% for MMH methods, $GTDM_M$, COM_M, FOF_H and above 99% for MVH, RLM_M. The use of data generated in the indirect step of standard methods of creation of texture features descriptor and proposing new ways of describing the internal form of the object together with the development of the method of creating the model gave an innovative approach to the problem of morphological description of the snow structure.

4.B 3. Emotion recognition and verification of its veracity

The smile is associated with a feeling of joy, pleasure, and contentment, however, as research shows, it can also occur in order to hide surprise or embarrassment [14]. Numerous experiences suggest that the simultaneous expression of emotions by lifting the corners of the lips and moving the muscles around the eyes (the so-called Duchenne smile) is synonymous with a sincere expression of happiness [12]. Research related to the recognition of emotions focused mainly on the analysis of the expression of mimic happiness, which is the easiest way to determine the sincerity of expression. Their goal was to develop a methodology to recognize the expressed emotion, its intensity and the sincerity based on the image or sequence of images depicting the face. I carried out part of the work myself as a part of the grant entitled "Emotion recognition" and collaborating with Prof. Bogdan Smołka in the project "Detection and recognition of non-verbal indicators of deception".

Recognition of emotions expressed through the change of facial expressions has become a popular topic of research in the last decade of the twentieth century. In the initial works, the optical flow method was used to track muscle movement [34] and the holistic approach [4],[15] was addressed. At that time, methods describing small mimic movements in the video sequences were also proposed [7],[8] and the Facial Action Coding System [13], describing which facial muscles move for each of the emotion, was developed. For the emotion analysis, the active shape model was

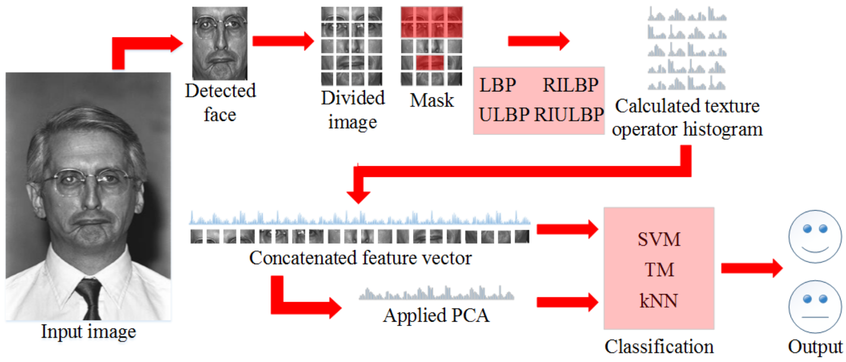


Figure 4: The scheme of the system enabling the recognition of images with smiling faces and those expressing neutral emotions. Source: [V].

used [29] but the use of LBP was a breakthrough in the field of emotion recognition [30],[38],[44].

In the conducted research works, the description of the image content, in other words the features describing the emotions, was defined using different versions of the local binary patterns. At the initial stage of research, attention was focused on the comparison of existing solutions developed to distinguish images of people smiling from those with a neutral facial expression. This allowed determining the methodology of conduct in the work aimed at developing a system whose task was to determine whether the presented smile is a spontaneous or fake reaction.

The creation of a feature vector, which is then to be classified into one of the two classes (smiling or neutral facial expression) can be implemented in various ways, e.g. as shown in Fig. 4. Describing the image content using the LBP method allows the recognition of facial expressions, but it also has its drawbacks. The vector of features describing a single image is very long, which is problematic for the classification methods used in this work, such as k-nearest neighbours method, SVM classifier or pattern matching method. In the works [poz13],[V] an innovative approach limiting the search for characteristics only to those regions where smile is visible (i.e. where there are lips and eyes – see "Mask" in Fig. 4) is described. In addition, in work [V], the impact of selecting the classification method on the effectiveness of the developed system was analyzed. The limitation of the length of the feature vector, apart from consideration of various LBP definitions, took place as a result of the reduction of its part describing this element of the area that did not enter the mask determining the location of the eyes and lips. The experiments carried out have shown that the use of masks not only does not adversely affect the effectiveness of the classification but even helps improve the results; the best performance is obtained for a system built on linear SVM, which correctly classified images in the Cohn-Kanade database with an accuracy of 96%. The next step was to use PCA [V], [VI] to remove redundant information from the feature vector. Such an approach allowed to significantly reduce the data describing the content of the image (up to several percent of the initial length), however, it was associated with deterioration of the accuracy of the classification by a few percent depending on the tested image database.

A further stage of the work was to propose a new feature descriptor (described

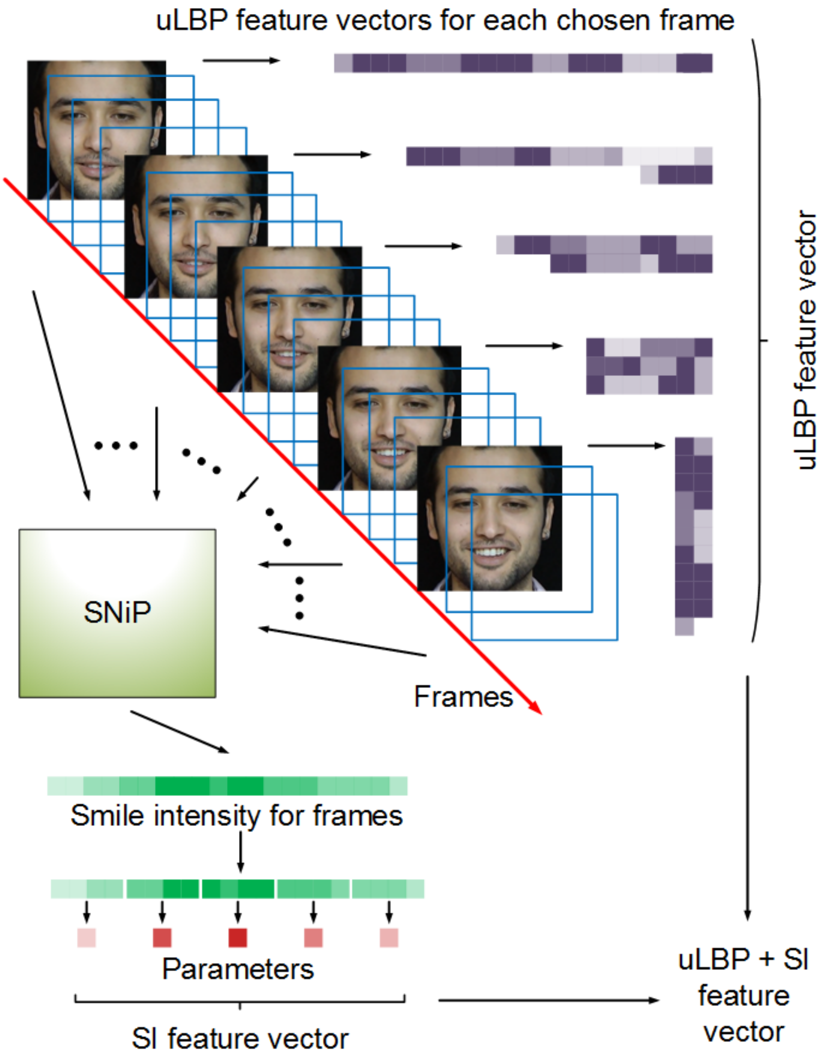


Figure 5: The way of creating a vector of features used to describe the sincerity of a smile. Source: [IV].

in the work [VII]), which was named "Power LBP" and tested the quality of the classification obtained using it to describe the content of the image. The most important of the experiments were described in the work [poz11], which states that the use of the new data description method allows obtaining better classification accuracy and achieve 98% efficiency.

Determining whether a smile is spontaneous or fake is difficult on the basis of one photo, that is why in the tests, the features describing the honesty of a smile are determined on the basis of the sequence of frames. The method proposed in the work [IV] evenly samples the sequence of images by choosing $N = 10$ frames and for each of them computes the feature vector uLBP (uniform LBP) [35] based on the methodology described earlier. These vectors are combined with each other and additionally, there is incorporated information about changes in the intensity of a smile (SI) that took place between successive frames (see Fig. 5). The descriptor goes to the input of the linear SVM classifier, which allows recognizing the sincerity of a smile with the efficiency of 75% for the UvA-NEMO database. It is worth noting that this innovative solution takes into account facial expressions recorded in just a few moments of the video sequence. On the other hand, parameters describing the intensity of a smile are calculated from all frames, which gives a global idea about changes in facial expressions occurring throughout the entire data series.

Another original solution was to divide the frame sequence into $N = 10$ segments and calculate for each of them the vector of features based on the three-dimensional version of LBP as it was reported in the work [poz8]. In this case, the frames belonging to the segment formed something like the volume of data, in which the vector of uLBP features was calculated in three orthogonal projections, after earlier normalization of the data set consisting of subtracting the averaged frame for a given segment. In this case, the focus was not on the texture characteristics alone, but on its changes compared to the average frame. Experiments have shown that this is an equally good method to achieve the effectiveness of detecting sincere emotions with a probability of 74%.

Subsequent studies have shown that there is a large correlation between changes in the intensity of the smile and its sincerity. In the work [poz6], it was proposed to calculate the intensity of a smile for the whole image (as it was in one of the previous works) and separate values that included changes only within the eyes or lips. Based on three functions of the intensity of the smile, parameters characterizing the sincerity of the expressed emotion were calculated. Such an approach allowed to achieve the effect of recognizing the sincerity of emotions at the level of 84%.

As a result of the conducted research, a comprehensive comparison of various techniques of a description of the texture and their impact on the recognition of 6 basic emotions such as happiness, fear, sadness, surprise, anger, and disgust was performed. In the work [poz3], a description of the data generated on the basis of LBP, the histogram of gradients (HoG) and Gabor wavelets was analyzed. Similarly, as in the case of recognizing smiles, many classifiers were considered. However, the best results (87% accuracy) were achieved for the linear SVM, which was trained using features derived from HoG.

4.B 4. The corneal endothelium morphologica structure description

Methods discussed earlier have also found their application in the analysis of medical data, an example of which is the description of the morphological structure of the corneal endothelium. The endothelium is a single layer of cells that forms the structure of the eye cornea, which can be observed by confocal or mirror microscopy. It is responsible for hydration of the cornea and indirectly for its transparency, which affects the ability to see [1]. Cells in the endothelium are characterized by a hexagonal shape that ensures their dense packing in space and allows for the exact coverage of the entire surface. Because these cells do not reproduce, their number decreases during human life [27]. Too large loss of them is the cause of trouble with eyesight. The place of a dying cell is occupied by neighbouring cells, which affects both the shape and number of cells in the region. These two characteristics are used to study the quality of the endothelium and to determine, for example, to what extent the process of eye healing occurs after surgical operations or injuries.

The problem of cell segmentation may seem trivial, however, uneven image illumination, changes in its sharpness and numerous artefacts make developing a fully automatic segmentation method a difficult task [poz5] for which no overall solution has been proposed. On the other hand, the analysis of the shape of individual cells and the determination of their features are strongly correlated with the quality of segmentation, which was also shown in [poz5].

4.B 4.1 Automatic segmentation of the cells of the endothelial layer of cornea

Describing the quality of the corneal endothelium, mainly made by analyses of the shapes of the cell is preceded by segmentation, which should be carried out in a fully automatic way, and give accurate results. In literature, a number of attempts have been made to develop such a solution, but without full success. There was proposed a number of techniques based on the method of the watershed, which in its best version are solutions of semi-automatic, requiring a suitable initialization of the segmentation process [6],[32],[43],[45]. Also attempts to solve this problem with the use of masks based on hexagons [31], and using a statistical analysis of the shape [17] were described. Other methods make use, inter alia of snakes [9], wavelets [26] or Voronoi diagrams [5]. Also, there were proposed a number of solutions based on artificial neural networks [16],[22],[25], which showed that it is possible to perform

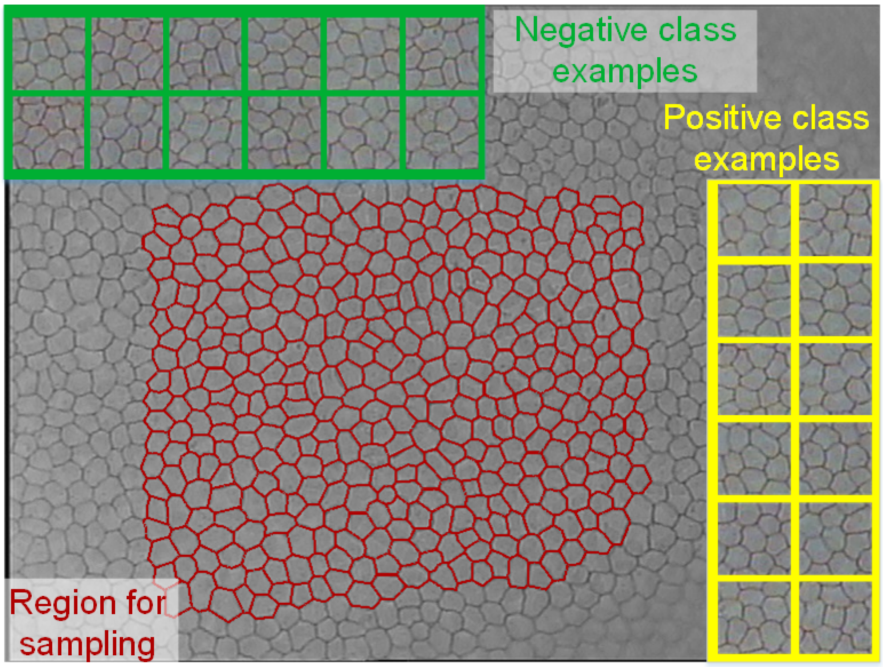


Figure 6: An example of training data for the AlexNet network. On the yellow background (on the right) there are examples of the positive class – the central pixel corresponds to the center of gravity of the cell. On the green background (at the top) there are examples of the negative class – the central pixel corresponds to the border of the cell. The red mask is marked with a manually prepared mask with correctly marked cells, in which areas the training images were sampled. Source: [II].

automatic segmentation, but its precision was insufficient or the number of missing borders too great that the solution could not be applied to clinical practice.

Aiming to develop a method that allows automatic segmentation of endothelial cells, the use of a convolutional neural network has been proposed. In the work [II] the solution was based on the AlexNet network [28]. This network has been trained to recognize 1000 classes of images depicting various objects. Thanks to the technique of transfer learning, it is possible to reduce the number of recognized classes (there were two classes in the described case) and to train the network with a small number of training images to recognize new classes. In the proposed solution, the class with positive data represented the centre of a cell (defined by the central pixel in the image with the resolution 64×64 pixels), while the class with negative examples represented the borders. Examples of training data along with the sampling site defined by the endothelial cell supplied in the "Alizarine" database [42] are shown in Fig. 6. Verification of the effectiveness of network trained using the 10-fold cross validation method on the validation set was 99%.

Then, the network for each pixel in the image subjected to segmentation cut out the region with the size corresponding to the size of the training data and made classification to one of the considered classes. Fig. 7 shows the obtained result. As can be seen, it is possible to automatically segment the corneal endothelial cells using a neural network. However, the obtained mosaic showing the borders is characterized by a high thickness, which makes the solution not precise enough. It is possible to

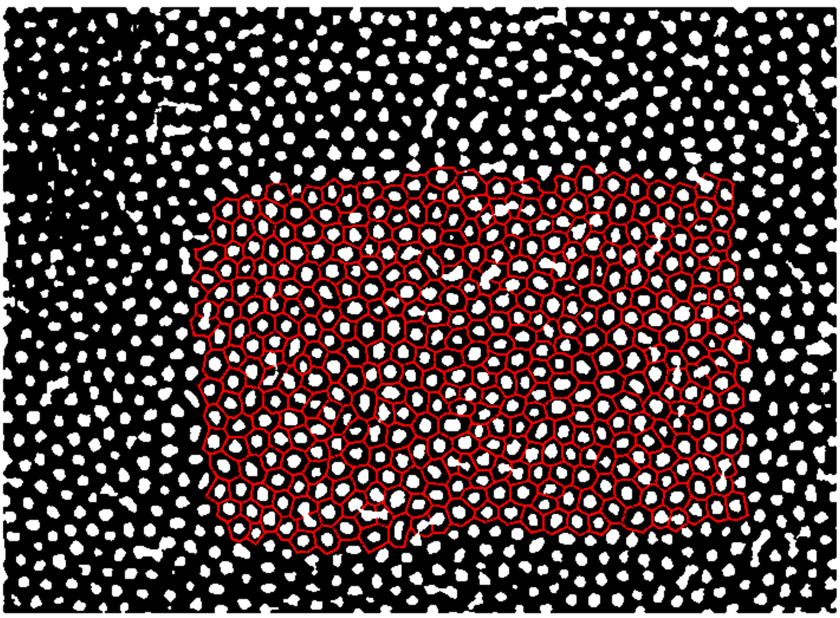


Figure 7: The result of segmentation of the corneal endothelium image by means of a convolutional neural network based on AlexNet. The pixels belonging to the positive class (the centre of the cell) are marked with white colour. The colour black corresponds to the classification of pixels to the negative class (border). Additionally, the course of the manually prepared mask available in the data set is shown in red. Source: [II].

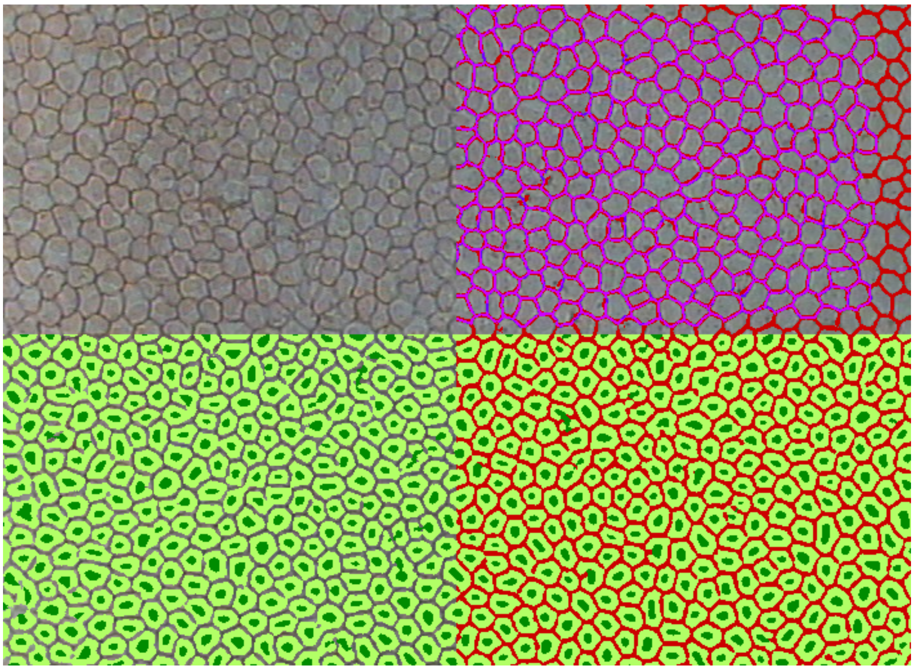


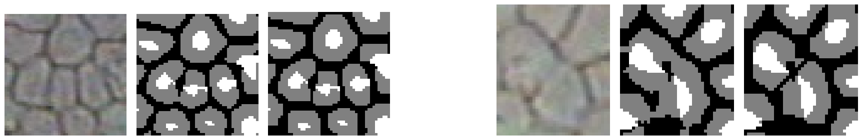
Figure 8: Presentation of the results of corneal endothelial segmentation using a convolutional neural network trained to recognize three classes: cell centre, cell body, and border. In the upper left corner, the original image is shown. The bottom left corner shows the result of automatic segmentation – the centre of the cell is marked in dark green, the body of the cell is light green and the borders remain transparent. The edge mask obtained for the method of thinning was added to the right. The upper right corner compares the accuracy of the automatically obtained mask – red – with a hand-prepared – blue colour. The pink colour shows the places where the masks overlap. Source: [I].

use the methods of thinning the mask so obtained, however, the results are not completely satisfactory.

An in-depth analysis of the obtained outcomes and shortcomings of the proposed solution resulted in the development of a new neural network architecture, details of which are described in the paper [I]. First, the optimal size of training data was selected experimentally ($32 \times 32 \times 1$). In addition, the model was expanded by a third class, which defined the cell body, i.e. the region belonging to the cell and at the same time not being its centre. The quality of segmentation prepared in this way is shown in Fig. 8, where the different classes are marked with different colours. As one can see, the proposed method finds borders very precisely. In addition, it enables image analysis not only in places with good contrast, where the mask was originally marked, but in the whole area.

The segmentation obtained in the presented manner is characterized by high precision, which in some cases can be improved by skeletonization. For this purpose, the best-fit [40] method was used. The solution also has cells connected to each other. However, by distinguishing the centre of the cell from the body of the cell it is possible to find errors by determining the index of connected cells:

$$MI(cell) = |\{c : \quad c \in C \quad \wedge \quad c \cap M(cell) \neq \phi\}|, \tag{2}$$



(a) Example merged cells division.

(b) Example of division of blurred cells.

Figure 9: Example of automatic division of connected cells. Source: [I].

where M is the set of detected cell bodies in the image, C is a set of cell centers, and c is the centre of the cell. This factor returns 0 for small cells in which the middle was not found, 1 for correctly detected cells, and higher values in the case of erroneous segmentation, which requires further processing. To this end, a division method has been developed that calculates the distance map from the centre of gravity (μ) of all cell centres belonging to the connected cell:

$$DM(p) = \sum_{p \in M(cell)} \sum_{\mu \in C(cell))} ||p - \mu||_2, \tag{3}$$

where p are the coordinates of the pixel belonging to the cell body, and $|| \dots ||_2$ is the Euclidean distance. The cell division line runs in the place of the minimum value in the received map. Examples of the method operation are presented in Fig. 9.

In conclusion, the proposed approach to segmentation of the corneal endothelium, using a convolutional neural network trained with three classes with additional cell search combined to separate them, gives very precise segmentation results. First of all, the system created in this way allows detection of corneal endothelial cells not only on images of good quality (contrast) but also when it is significantly blurred. The distinguished borders run exactly between the two cells and are in the same place as on the manually selected masks. Many measures that allow comparison of segmentation results show high consistency, as described in work [I].

4.B 4.2 Analysis of the morphological structure of the cells of the endothelial layer of the cornea

The only way to qualitatively compare the corneal endothelium of the same patient at different time periods (or different patients) is to analyze the characteristics resulting from the shape and distribution of endothelial cells on a microscopic image. In medicine, it has been proposed to use directly the cell size [41] and more advanced measures based on the coefficient of variation of the cell size [10] and the measure of hexagonality [11], which calculates the probability of a hexagonal cell in the image. These measures change their values with the change in the endothelium state [37] but are not as stable as the coefficient of cell side length variation in various clinical conditions.

As discussed in the section 4.B 2.1, many measures have been proposed in the field of image processing to describe the shape. Therefore, in the studies presented in the paper [III], it was checked whether it is possible to directly transfer these measures to the description of the corneal endothelium. An additional research aspect was the determination of the relationship between different shape features, which allows eliminating redundant data and at the same time better characterize the endothelium. The analysis includes shape description methods based on the statistical description of the data [19], which takes place in the case of: spatial moments of various order; their improved version resistant to translation – central moments; normalized central moments, which are additionally resistant to change of scale, and moments suggested by Hu [23], which add resistance to rotations to the advantages presented by previous methods. Topological attributes were also taken into account in the conducted research [19, 24], which included: cell size, length of its borders and parameters of shape description. Among the shape parameters can be named those allowing to distinguish round objects from elongated ones (e.g. Malinowska, shapeless, roughness measure, etc.), focusing on determining the elongation of the object in one direction (e.g. Feret measure) or trying to describe a complex contour course by analyzing dependencies between points placed on it and points inside the object (e.g. Blair-Bliss, Danielsson, Haralick, etc. measures). In total, 55 methods of describing the shape of corneal endothelial cells have been analyzed.

The values describing the shapes of particular cells were determined for images from the Endothelial Cell "Alizarine" collection. Their comparison was made possible by using a measure of the scattering value of a given feature:

$$\text{Param} = \frac{1}{\mu_p}\sqrt{\frac{1}{N}\sum_{i=1}^{N}(p_i - \mu_p)^2}, \tag{4}$$

where p_i is a feature counted for ith cell in the image, μ_p is the average value of the calculated feature, and N is the number of cells in the image. The statistical analysis of the results obtained allowed to distinguish four groups of features that are characterized by a strong correlation of results and a dozen features that do not show such a dependence. Therefore, it was found that cell size, circularity measure (defined as $\frac{circumference^2}{area}$), most central moments and normalized central moments as well as Hu moments are independent. Further research has shown that the coefficients proposed in medicine are not correlated with any of the measures considered, i.e. it is possible to create a complementary set of features describing the quality of the endothelium.

4.B 5. List of the most important original achievements

For the most important of original achievements related to the recognition of objects based on information contained in their external or internal form I consider:

- Proposing a series of measures (concavity number, corner number, min-max distance, min-max distance from the centre of the mass, volume) describing the morphological characteristics of snowflakes.
- Proposing feature vectors calculated based on min-max histogram and mean-variance histogram.
- The use as a vector of features describing the content of the image showing the snowflake of intermediate matrices calculated in methods FOF_H, COM_M, GTDM_M i RLM_M.
- Proposing the use of masks to shorten the vector of features needed to describe the image expressing happiness.

- Developing the method of analysing the sincerity of a smile based on features describing the local texture characteristics and the intensity of a smile.
- Development of the method of automatic and precise corneal endothelial segmentation using deep neural networks trained using a distinction of three classes of object description (border, cell body, and cell centre) along with the proposed supporting method, allowing the division of connected cells.
- Analysing the correlation of available shape parameters used in the field of image processing with those used in medicine in order to find an optimal set of parameters describing corneal endothelial cells.

4.B 6. Feature works

As part of a further research, I plan to apply the developed methods to other issues related to, inter alia, medicine. I also intend to develop new methods based on the analysis of objects in images by means of their description through the information contained in the texture or shape factors. As part of cooperation with many centers, I conduct or start research on the following issues:

- Development of an automatic method of segmentation of cancerous cells in tissues stained with eosin and hematoxylin.
- Finding a method that allows normalization of colors in images of tumor tissues stained with eosin and hematoxylin, which should simplify the process of their segmentation.
- Development of the segmentation method of concretion on images from the seabed in order to automatically determine the volume of deposits.
- An analysis of the effectiveness of using maps based on a texture in order to increase diagnostic possibilities based on X-ray images of teeth.
- Development of a method for the detection of caries or apical changes in teeth X-ray images.
- Development of a method for segmentation of rock grains images for the purposes of analysis grain class.

5. Other scientific and research achievements.

    a) Scientific achievements

In addition to the works described in the presented series of publications, I carried out research in the following topics: (i) segmentation of inflammatory states in ultrasound images, (ii) visualization of underground coal gasification and (iii) I have developed a software supporting neural network structure analysis and (iv) I took part in many other research topics related to image analysis, or the creation of web applications for various applications. I discuss these investigations in the following point 5.A. Section 5.A.6 contains a list of selected, more important works that were not part of the series of publications.

5.A 1. Segmentation of inflammatory states in ultrasound images

Another research topic I was working on was the development of a method that allows automatic detection of areas in which arthritis is visible on ultrasound images. I conducted this research in cooperation with Prof. Konrad Wojciechowski and Prof. Bogdan Smołka as part of the project "Automated assessment of joint synovitis activity from medical ultrasound and power Doppler examinations using image processing and machine learning methods". As a result of the activities carried out, an innovative solution based on a statistical analysis of grey levels to determine the arthritis region was created. In the work [poz7] a method was found to find the location of the skin and bones of the finger, which allowed to limit the region of search for inflammation. Then in the work [poz9] a map of confidence was introduced, which was used to determine the accuracy of the found inflammation and the elimination of incorrectly designated regions. Work [poz10] is a collective summary of the achievements of the entire team working on segmentation of arthritis.

5.A 2. Visualization of underground coal gasification

While working at the Central Mining Institute, where I carried out the project "Visualization of the cavity development in underground coal gasification processes" I dealt with the problem of visualization of the process of underground coal gasification with the team under my direction. As part of the work, a mathematical model was developed describing the course of the underground coal gasification process, which is presented in the work [poz15]. In addition, an application was created that based on the original data acquired during the experiments using a geo-radar or using the developed mathematical model allows for three-dimensional simulation of the process of underground coal gasification along with an analysis of its course. A detailed description of the developed solution can be found in works [poz14], [poz17].

5.A 3. Analysis of the structure of neural networks

Another element of research related to the morphological analysis of cells is the analysis of the structure of neural networks, which aims to approximate the functioning of the population of neurons within the central nervous system. The study of such a network consists of considering the characteristics (shape) of neurons and their distribution within particular nerve structures. The CAS (cell annotation software) program was implemented for the purpose of such research conducted at the Pavlov Institute in St. Petersburg, whose task was to facilitate data analysis by automatic detection of neural cells based on the innovative application of the SDA method (statistical dominance algorithm) [39] and analysis of cell shapes and their dispersion in user-selected regions. The full usability of the developed programming solution has been described in work [poz2] [1].

[1] The software is available under the link `http://home.agh.edu.pl/~pioro/cas/`

5.A 4. Other research topics

In the last ten years, I have participated in many research projects that resulted in numerous publications. A brief summary of the work is below:

- Together with Marcin Michalak Ph.D. from the Institute of Informatics at the Silesian University of Technology, I conducted research aimed at development of oblique rules for decision-making. Determining the optimal way of rules creation was the result of using the principal components analysis to detect the division directions for each rule. The results of the research were presented in works [poz16], [poz18].
- I participated in the development of a database application [poz12], which allowed to collect and analyse mercury data. These works were carried out as part of a project led by Prof. Barbara Białecka, titled "Development of the mercury content database in domestic coals, technological guidelines for its further reduction along with the definition of benchmarks for national mercury emission factors".
- I have suggested the idea of the method of lighting normalization in over-exposed images, which was described in the work [poz19].
- I have developed a method for describing chain deformations based on motion analysis in an image that has been described in [poz20] and has been used so far in research conducted by employees of the Central Mining Institute.
- Under my supervision the work [poz4] analysing various aspects of JavaScript and its extensions in the context of creating optimal web applications was created.
- I proposed using texture feature maps as an alternative way of visualization of X-ray data supporting dental treatment [poz1].

5.A 5. Summary

After obtaining the doctoral degree, I was the author or co-author of 56 publications, from which 10 became part of the publication series constituting the habilitation achievement. At point 5.A.6 there is a list of 21 publications selected from those that were not part of the series. This list contains only reviewed items. These publications summarize research that I carried out in cooperation with various research teams – among them were both funded research and development projects (referred to below in point 5.B) as well as projects implemented independently as part of individual cooperation that I established. Total impact factor (IF) according to JCR of all my post-doctoral publications is 14,15, h-index equals 4, and the total number of the points of the Polish Ministry of Science and Higher Education is 495.

5.A 6. The list of selected publications outside the series

[poz1] R. Obuchowicz, K. Nurzyńska, B. Obuchowicz, A. Urbanik, A. Piórkowski, "Caries detection enhancement using texture feature maps of intraoral radio-

graphs", *Oral Radiology*, vol. , pp. 1–13, 2018 /IF = 0.466; 15 pts of Polish Ministry of Science and Higher Education/

[poz2] K. Nurzyńska, A. Mikhalkin, A. Piórkowski, "CAS: Cell Annotation Software - research on neuronal tissue has never been so transparent", *Neuroinformatics*, vol. 15, nr 4, pp. 365-382, 2017 /IF = 3.852; 35 pts of Polish Ministry of Science and Higher Education/

[poz3] K. Nurzyńska, "Emotion recognition: the influence of texture's descriptors on classification accuracy", in *Beyond Databases, Architectures and Structures. Towards Efficient Solutions for Data Analysis and Knowledge Representation*, S. Kozielski et al., Eds., pp. 427–438 vol. 716, Springer International Publishing Switzerland, 2017. /Web of Science, 15 pts of Polish Ministry of Science and Higher Education/

[poz4] A. Młynarski, K. Nurzyńska, "Comparative analysis of JavaScript and its extensions for web application optimization", in *Beyond Databases, Architectures and Structures. Towards Efficient Solutions for Data Analysis and Knowledge Representation*, S. Kozielski et al., Eds., pp. 539–550, vol. 716, Springer International Publishing Switzerland, 2017. /Web of Science 15 pts of Polish Ministry of Science and Higher Education/

[poz5] A. Piórkowska, K. Nurzyńska, J. Gronkowska-Serafin, B. Selig, C. Boldak, D. Reska, "Influence of applied corneal endothelium image segmentation techniques on the clinical parameters", *Computerized Medical Imaging and Graphics*, vol. 55, pp. 13–27, 2016 /IF = 2.435; 25 pts of Polish Ministry of Science and Higher Education/

[poz6] M. Kawulok, J. Nalepa, K. Nurzyńska, B. Smołka, "In Search of Truth: Analysis of Smile Intensity Dynamics to Detect Deception", in *Advances in Artificial Intelligence - IBERAMIA 2016*, M. Montes y Gómez, H.J. Escalante, A Segura, J. Murillo, Eds., pp. 325–337, Springer International Publishing, 2016. /Web of Science, 15 pts of Polish Ministry of Science and Higher Education/

[poz7] K. Nurzyńska, B. Smołka, "Automatic finger joint synovitis localization in ultrasound images", in *Real-Time Image and Video Processing 2016*, N. Kehtarnavaz; M. F. Carlsohn, Eds., pp. 98970N-98970N-11, vol. 9897, SPIE Proceedings, 2016. /Web of Science, 15 pts of Polish Ministry of Science and Higher Education/

[poz8] K. Nurzyńska, B. Smołka, "Smile veracity recognition using 3D texture features for image sequence processing", in *2016 Signal Processing: Algorithms, Architectures, Arrangements, and Applications (SPA)*, pp. 125–129, IEEE, 2016.

[poz9] K. Nurzyńska, B. Smołka, "Segmentation of finger joint synovitis in ultrasound images", in *2016 IEEE Sixth International Conference on Communications and Electronics (ICCE)*, pp. 335–340, IEEE, 2016. /Web of Science, 15 pts of Polish Ministry of Science and Higher Education/

[poz10] K. Wojciechowski, B. Smołka, R. Cupek, A. Ziembiński, K. Nurzyńska, M. Kulbacki, J. Sagen, M. Fojcik, P. Mielnik, S. Hein, "A machine-learning approach to the automated assessment of joint synovitis activity", in *Computa-*

tional Collective Intelligence, N. T. Nguyen, L. Iliadis, Y. Manolopoulos, B. Trawiński, Eds., pp. 440–450, Springer International Publishing, 2016. /Web of Science, 15 pts of Polish Ministry of Science and Higher Education/

[poz11] K. Nurzyńska, B. Smołka, "Recognition between smiling and neutral facial display with power LBP operator", in *IEEE EUROCON 2015 - International Conference on Computer as a Tool (EUROCON)*, pp. 1-6, IEEE, 2015. /Web of Science, 15 pts of Polish Ministry of Science and Higher Education/

[poz12] S. Iwaszenko, K. Nurzyńska, B. Białecka, "MercuryDb - A database system supporting management and limitation of mercury content in fossil fuels", in *Beyond Databases, Architectures and Structures*, S. Kozielski, D. Mrozek, P. Kasprowski, B. Małysiak-Mrozek, D. Kostrzewa, Eds., pp. 530–539, Springer International Publishing, 2015. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

[poz13] K. Nurzyńska, B. Smołka, "Facial displays description schemas for smiling vs. neutral emotion recognition", in *Artificial Intelligence and Soft Computing*, L. Rutkowski, M. Korytkowski, R. Scherer, R. Tadeusiewicz, L. A. Zadeh, J. M. Zurada, Eds., pp. 594–605, Springer International Publishing, 2015. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

[poz14] S. Iwaszenko, K. Nurzyńska, "GPR data visualization for underground coal gasification process research", in *2014 IEEE Geoscience and Remote Sensing Symposium*, pp. 1635–1638, Quebec, Kanada, 2014. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

[poz15] K. Nurzyńska, T. Janoszek, S. Iwaszenko, "Modelling test of cavity growth during underground coal gasification process using CFD method", in *2014 International Conference on Information Science, Electronics and Electrical Engineering*, Jiang, X; Li, S; Dai, Y; et al., Eds., pp. 415–419, vol. 1, IEEE, 2014. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

[poz16] M. Michalak, K. Nurzyńska, "Advanced oblique rule generating based on PCA", in *Artificial Intelligence and Soft Computing*, L. Rutkowski, M. Korytkowski, R. Scherer, R. Tadeusiewicz, L. A. Zadeh, J. M. Zurada, Eds., pp. 561–573, Springer International Publishing, 2014. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

[poz17] K. Nurzyńska, S. Iwaszenko, T. Choroba, "Database application in visualization of process data", in *Beyond Databases, Architectures and Structures*, S. Kozielski, D. Mrozek, P. Kasprowski, B. Małysiak-Mrozek, D. Kostrzewa, Eds., pp. 537–546, Springer International Publishing, 2014. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

[poz18] M. Michalak, K. Nurzyńska, "PCA based oblique decision rules generating", in *Adaptive and Natural Computing Algorithms*, M. Tomassini, A. Antonioni, F. Daolio, P. Beusser, Eds., pp. 198–207, Springer Berlin Heidelberg, 2013. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

[poz19] K. Nurzyńska, R. Haraszczuk, "Detection and normalization of blown-out illumination areas in grey-scale images", in *Advances in Visual Computing*, G.

Bebis, R. Boyle, B. Parvin, D. Koracin, Ch. Fowlkes, S. Wang, M-H. Choi, S. Mantler, J. schulze, D. Acevedo, K. Mueller, M. Papka, Eds., pp. 282–291, Springer Berlin Heidelberg, 2012. /Web of Science, 13 pts of Polish Ministry of Science and Higher Education/

[poz20] M. Michalak, K. Nurzyńska, A. Pytlik, K. Pacześniowski, "Analysis of deformation of mining chains based on motion tracking", in *Advances in Visual Computing*, G. Bebis, R. Boyle, B. Parvin, D. Koracin, Ch. Fowlkes, S. Wang, M-H. Choi, S. Mantler, J. schulze, D. Acevedo, K. Mueller, M. Papka, Eds., pp. 588–596, Springer Berlin Heidelberg, 2012. /Web of Science, 13 pts of Polish Ministry of Science and Higher Education/

[poz21] K. Nurzyńska, M. Kubo, K-I. Muramoto, "Snow particle automatic classification with texture operators", in *2011 IEEE International Geoscience and Remote Sensing Symposium*, pp. 2892–2895, IEEE, 2011. /Web of Science, 10 pts of Polish Ministry of Science and Higher Education/

b) Research and research-and-development projects:

1) I received a Rector's quality grant II-level awarded by the Rector of the Silesian University of Technology in 2019 (02/020/RGJ19/0168).
2) I received a habilitation grant awarded by the Rector of the Silesian University of Technology in 2018 (02/020/RGH18/0151).
3) In 2010, I applied for a project titled "Visualization of the cavity development in underground coal gasification processes". The application received funding under the LIDER project (II competition) at the National Centre for Research and Development (No. LIDER/09/30/L-2/10/NCBiR/2011) and in 2011–2014 I managed this project.
4) "Working in a Collaborative Factory of the Flight Simulators Branch of RISE", 2019–2023, grant from Maria Skłodowska-Curie Research and Innovation Staff Exchange Program, Horyzont 2020, (main executor).
5) "Pain of endangered Ego. Ego-evident and implicit self-esteem, stress reaction in the face of social threat and thresholds of sensation and tolerance to pain", 2017–2020, a grant under the Sonata 12 program of the National Science Centre, No. 2016/23/D/HS6/02810 (executor).
6) "Emotions recognition", 2016–2017, Project of Statutory Research for Young Scientists (BKM) of the Institute of Informatics of the Silesian University of Technology (project manager).
7) "Automated assessment of joint synovitis activity from medical ultrasound and power Doppler examinations using image processing and machine learning methods", MEDUSA, 2009–2016, a grant under the Polish-Norwegian Research Program, Norwegian Financial Mechanism 2009–2014, No Pol-Nor/204256/16/2013 (executor).
8) "Detection and recognition of non-verbal deceptions indicators", 2013-2016, a grant under the Opus National Science Center program, No. DEC-2012/07/B/ST6/01227 (executor).

9) “Development of the mercury content database in domestic coals, technological guidelines for its further reduction with the definition of benchmarks for national mercury emission factors”, 2013–2016, grant financed by the National Centre for Research and Development, No. PBS2/A2/14/2013 (executor).
10) “Establishment of a new specialization in doctoral studies in the Discipline of Information Technology, at the Faculty of AEII of the Silesian University of Technology: Data Mining ”, 2009–2013, grant financed by the European Union under the European Social Fund, UDA-POKL.04.01.01-00-106/09 (young doctor).
11) “Environmental monitoring in East Asia”, 2008–2012, grant Grant-in-Aid for Scientific Research funded by Japan Society for the Promotion of Science, No. 20254001 (executor).

c) Additional information:

1) I reviewed 17 manuscripts submitted to JCR journals:
   i EURASIP Journal on Image and Video Processing /IF = 2.455/,
   ii Remote Sensing /IF = 3.406/,
   iii Journal for Numerical Methods in Biomedical Engineering /IF = 2.338/,
   iv Mathematical Problems in Engineering /IF = 0.802/
   v International Journal of Machine Learning and Cybernetics /IF = 1.699/,
   vi Neuroinformatics /IF = 3.2/,
   vii IEEE Journal of Biomedical and Health Informatics /IF = 3.451/,
   viii IET Computer Vision /IF = 0.878/,
   ix Atmospheric Research /IF = 3.778/,
   x Meteorological Applications /IF = 1.411/.
2) I acted as Steering Committee Chair na International Symposium on Environmental Monitoring in East Asia, 27-29 Sep. 2010, Kanazawa, Japan.
3) I acted as Technical Program Committee (TPC) Member for IEEE ICCE 2018 (2018 IEEE Seventh International Conference on Communications and Electronics, ICCE), 18-20 Jul 2018. w Hue City, Wietnam.
4) I akted as Associate Editor in Open Computer Science journal from 2010 to 2015.
5) I supervised 7 master thesis and 17 bachelors thesis.
6) Since 2011 I lead the team preparing “Activity Report” of Institute of Informatics, as a part of our work 4 publications popularizing the research were prepared, each around 200 pages.
7) I took part in 33 international and national conferences.
8) I conducted teaching classes in Polish at full-time and part-time studies, first and second degree in the field of Computer Science and in English on the Macrofaculty of the following subjects:

i. Fundamentals of Computer Programming.
ii. Computer Programming 2.
iii. Computer Programming 3.
iv. Computer Programming 4.
v. Introduction to Compilers.
vi. Computer Graphics.

9) I have prepared teaching materials for my subjects in the field of Computer Science and at Macrofaculty.
10) I have prepared a lecture in English for Ph.D. candidates entitled "Image Analysis".

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