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DOCTORAL SCHOOL “CONSTANTIN BELEA”
FACULTY OF AUTOMATION, COMPUTERS AND ELECTRONICS
FIELD MECHATRONICS AND ROBOTICS

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PHD THESIS SUMMARY

CONTRIBUTIONS TO THE IMPROVEMENT OF THE COGNITIVE - AFFECTIVE REACTIONS RECOGNITION SYSTEMS

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Contents

The importance and relevance of the topic

The face is our main focus in social relations (interactions) playing an important role in transmitting the identity and emotion.

The computing environment is heading towards projects centered on the human factor instead of projects centered on the computer [58], and the human tendency to communicate a lot of information through emotional states and expressions. In the near future people won't interact with machines only through intentional inputs, but also through their behavior and emotional state [94], [75].

Therefore, the research community in the artificial vision field considered the automatic analysis and recognition of facial expressions very interesting. There are many domains of application, which can benefit from a system that can recognize facial expressions, such as, the interaction human-computer, entertainment, medical applications, for example, pain detection, social robots, lie detection, interactive video applications and behavior monitoring applications.

In this thesis the focus is on the conception, the testing, the simulation and experimentation with algorithms with the purpose of obtaining recognition of the human cognitive-affective reactions. In order to classify the human emotions in visual recognition algorithms, 3 face components which vary very much from an emotion to the next were taken into consideration, namely: eyebrows, eyelids and mouth.

Chapter 1. Fundamental concepts in the cognitive-affective reactions capture systems

In the first chapter an introduction to artificial vision systems for image acquisition, their application fields, current and future trends, emotion models, types of algorithms for recognizing cognitive-affective reactions are presented.

Chapter 2. The state of the art of the capture systems and algorithms for cognitive-affective reactions recognition

In the second chapter a bibliographic state of the art cognitive-affective reactions capture systems and of the algorithms for recognizing cognitive-affective reactions are presented. A detection algorithm of 5 emotional states based on the correspondence between FACS coding system and the action units of the face muscles AU2, AU15, AU20, AU26 (fig. 2.18) has also been created, the implementation being realized on an experimental system with the android robot Elvis Alive (fig. 2.19), the results being presented in fig. 2.20.

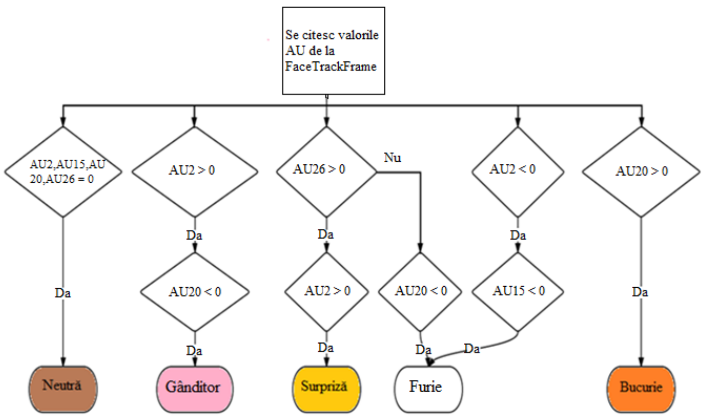


Fig. 2.18. FACS initial detection algoritham

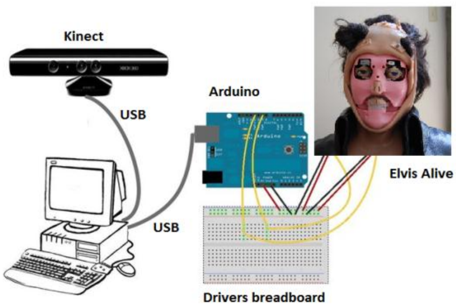


Fig. 2.19. Proposed experimental system based on Kinect and the Arduino Uno structure[30]

a) surprise b) thinking c) joy d) neutral

Fig. 2.20. The experimental facial expressions of the android [30]

Chapter 3. Methods of recognition and artificial vision algorithms for processing and describing images

In this chapter : the video cameras calibration, the optical and geometric transformation for images; 4 algorithms for determining fractal dimensions and computation relations for determining deterministic features, shape recognition algorithms through three methods: pattern matching methods, methods based on decision function and synthetic methods; and the chapter's conclusions are presented.

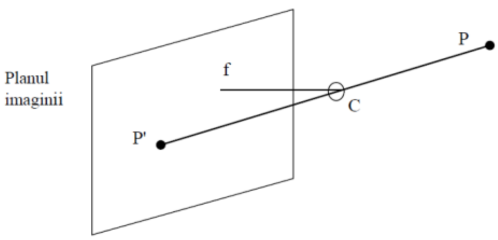
The geometrical calibration of the video camera is a necessary condition for any artificial vision system in which the extraction of the tridimensional image from the image plane is desired. The calibration method is classified according to the considered camera type (pinhole, pinhole with distortions, etc.) or according to the parameters estimation model (linear and nonlinear methods) [3].

Another classification is the calibration method:

- artifacts based calibration (or photometric [4]): this method is based of observing a 3D model, whose geometry is known [3].
- auto calibration.

In the simplest camera approximation is a spherical lens with the optical center in C and the distance to the f. P' image plane is the P point projection, in space, in the image's plane as in [12] fig. 3.1.

All the images appear upside-down in the image's plane, this being a disadvantage, and to eliminate, we place through convention, the image's plane in front of the lens as in [12] fig. 3.2.



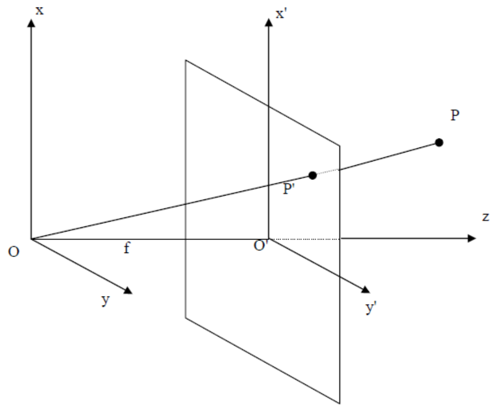


Fig. 3.1. The image's plane formation [12] Fig. 3.2. The movement of the image's plane [12]

Finding the P' projection coordinates if the real point P coordinates are known is called direct perspective transformation and finding the geometric place of the P points if the P' projection coordinates are known is called revers perspective transformation.

Chapter 4. The description and analysis of the algorithms for cognitive-affective reactions recognition

In chapter 4 a classification of the algorithms of the cognitive-affective reactions is described, indicating the advantages and disadvantages of each.

For the recognition of the cognitive-affective emotions there were used the most obvious facial features (mouth, eyes, eyebrows). The recognition algorithms of the emotions use as

decisional base these facial features to which phases of identification, matching, mathematical calculation and correspondence are applied, with the aim of classifying the emotions.
The general approach in the automatic analysis of the facial expression is formed from three steps: (showed in fig. 4.1):

- Face detection and its tracking;
- Feature extraction;
- The classification of the expression/recognition .

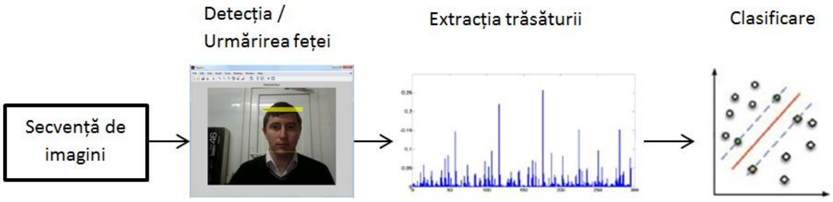


Fig. 4.1. Pipeline systems for the automatic recognition of facial expressions.

The described algorithms are the following: k-Nearest Neighbors – k-NNs; Suport Vector Machines – SVMs; Maximum-Likelihood Estimation – MLE; Mitchell, Demyanov and Malozemov – MDM; Linear Discriminant Analysis – LDA; Gaussian Mixture Model – GMM; Artificial Neural Networks - ANNs; Hidden Markov Model - HMM; Decision tree algorithms.
Some advantages and disadvantages of the described algorithms are:

- The k-NNs algorithm presents as main advantage the usage of the full set of training as a model. On the other hand its disadvantages are: high computation time and the inaccuracy in the way it treats data located in the border regions of the classes.
- Using the decision trees in the cognitive-affective biomimetic systems confers its advantages: producing efficient models, which are easy to understand, easy to use and are not affected by the lack of the data values.
- The main advantage of the SOMs network (Self-Organized Maps) is that the network accepts multidimensional data which it transforms in a smaller map.
- The main advantage of the SVMs algorithm is low computing time, because it does not require the transposition of all inputs in a big space.

Chapter 5. Simulations, experiments and results based on the algorithms for the recognition of the cognitive-affective reactions

In this chapter creations, simulations and experiments with visual recognition algorithms of the cognitive-affective reactions are presented.

The identification process of the face was obtained based on the algorithm created using principal component analysis technique - PCA. Fig. 5.8 shows the experimental results [31].

The experiment was performed using the Matlab R2012b, which is installed on a computer with the configuration: Intel Celeron 1.5 GHz, 2 GB RAM and 1.3 megapixel video camera.

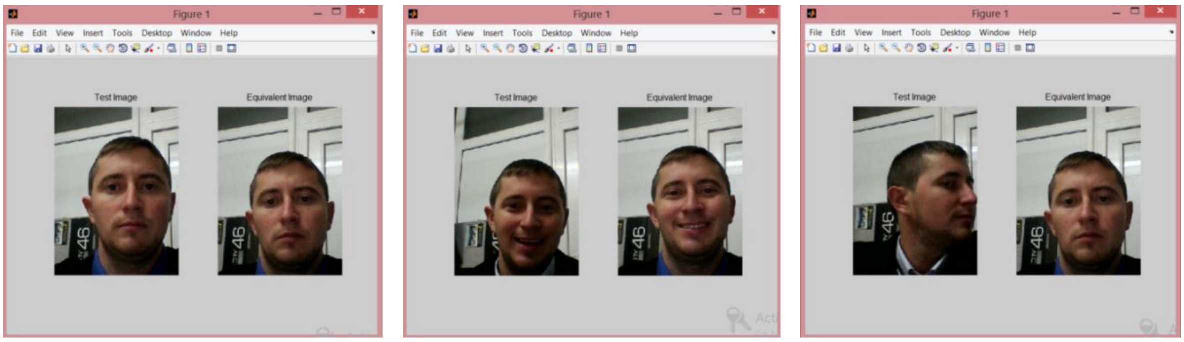


Fig. 5.8 The face identification in 3 tests [31]

An implementation of the PCA algorithm is a control access experimental system (opening / closing a door) its security being provided by the access through the facial recognition of each person. Figure 5.9 shows the block diagram for the implementation of the PCA algorithm.

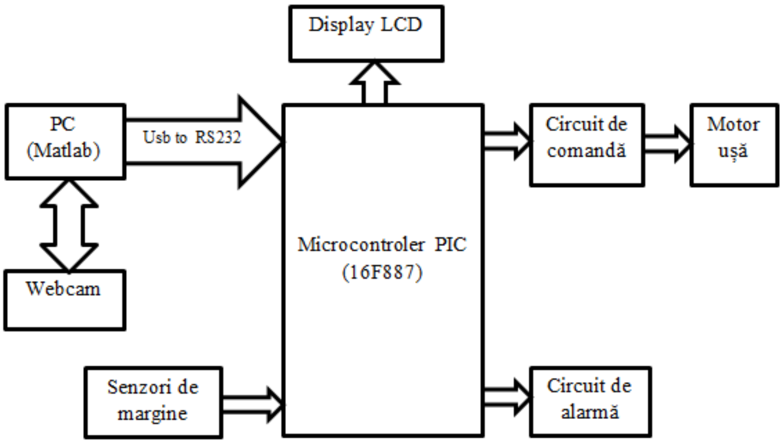


Fig. 5.9. The block diagram of an automatic door opening system using face recognition by the PCA technique

The physical part of the system contains the following components: PIC microcontroller 16F887, control circuit, limit switch sensors (optical couplers), USB converter - RS232, DC motor, PC, webcam and an alarm circuit.

When the image of an authorized person (matching a human face from the existing database) is identified by the PCA algorithm, the door will open automatically, as shown in figure 5.18. If a human face image to be tested was not found in the database of the system, it is unidentified, the door remains closed, the result is shown in figure 5.19.

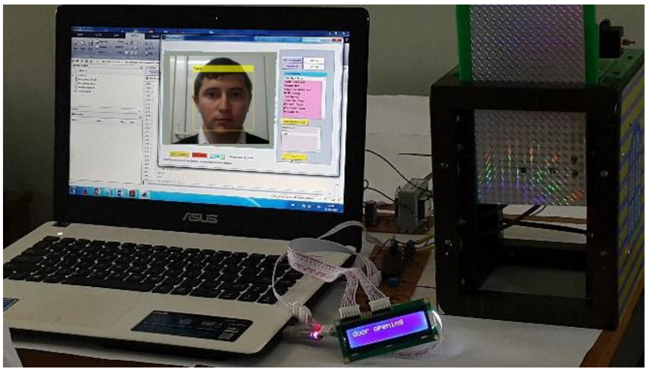


Fig. 5.18. Experimental test for an identified person

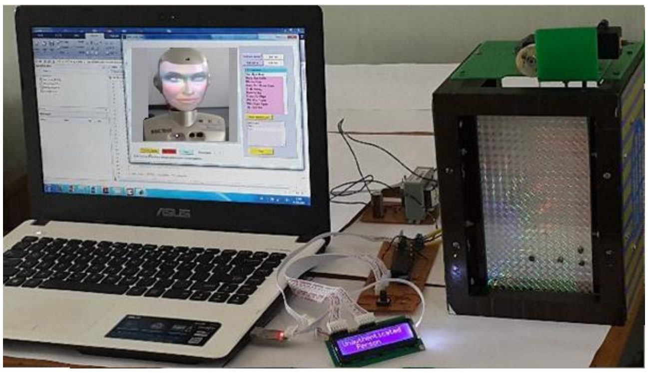


Fig. 5.19. Experimental test for an unidentified person

For the experimental study with the algorithms for detection and face tracking: Viola-Jones, MeanShift and CAMShift, I used a PC with Intel Core i3-2100 CPU processor and 4GB of memory. I tested two videos in Matlab 2012b using the Computer Vision System Toolbox.

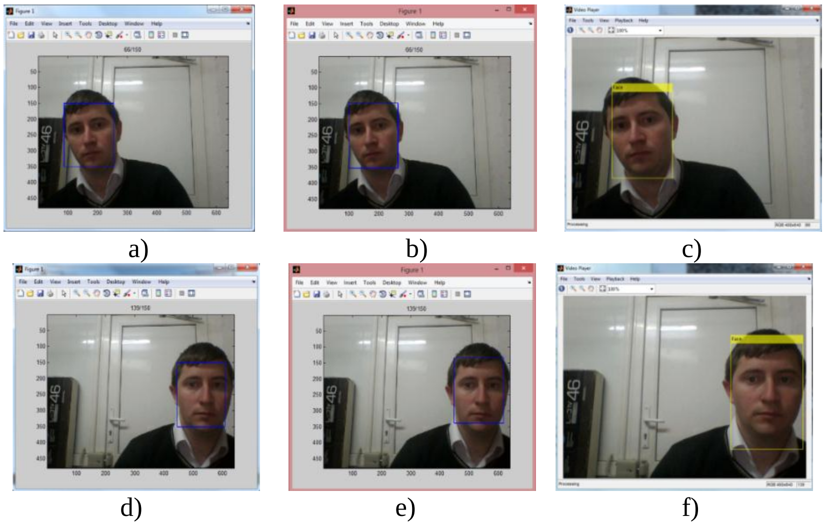


Fig. 5.22. Face tracking results in frames 66 and 139 from the first video sequence by using methods: CAMShift (a, d), MeanShift (b, e), Viola-Jones algorithm (c, f) [35]

Fig. 5.23. Face tracking results in frames 86 and 163 from the second video sequence by using methods: CAMShift (a, d), MeanShift (b, e), Viola-Jones algorithm (c, f) [35]

From the experimental results with the 3 algorithms for detection and face tracking: MeanShift, CAMShift and Viola-Jones we can say that the algorithms MeanShift and CAMShift have very good results even if a person's face is covered with an object or human parts with the same hue. Viola-Jones algorithm is the fastest, but has bad results if the face is covered by other objects.

The simulation results obtained using the backpropagation algorithm were performed using a PC system with the configuration: Intel Core i3-2100 processor and 4GB memory. The simulation itself was performed in Matlab R2012b using the model recognition tool through a neural network. This simulation validates that the system can classify seven emotional states.

The structure of the feedforward network is shown in figure 5.26 [37] and is composed as follows: the input level, consists of three input vectors, intermediate level (hidden), contains five neurons and the output level, contains seven neurons, one for each emotional state.

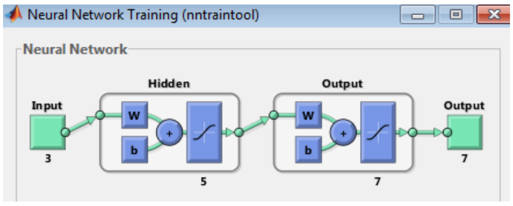


Fig. 5.26. The feedforward structure [37]

The used neural network is built using the backpropagation algorithm using the function of the conjugate scaled gradient type (train scg). The three input vectors, each have forty-one different values being appointed feature vectors of the form 3x41, resulting in 123 elements) being associated with 123 neurons. The output vector is of the form 7x1, resulting seven elements corresponding to the seven classes: happiness, sadness, fear, anger, surprise, disgust and neutral.

In figure 5.28 [37] the confusion matrix for the following processes is shown: training, validation, testing, and all mixed together. For the training process, the conclusion is that from the first array that the network has very good results for the emotions: sadness, fear, anger and neutral. The weaker results are for the emotions: happiness, surprise and disgust, the weakest being for happiness class that has a percentage of 6.9% confused with the second class (sadness). For the validation and testing processes there aren't confusions and for the mixed process, the confusion is kept whole for the 3 classes listed, but now the biggest confusion is for the surprise class (7.3%), where this class is confused with the fear class.

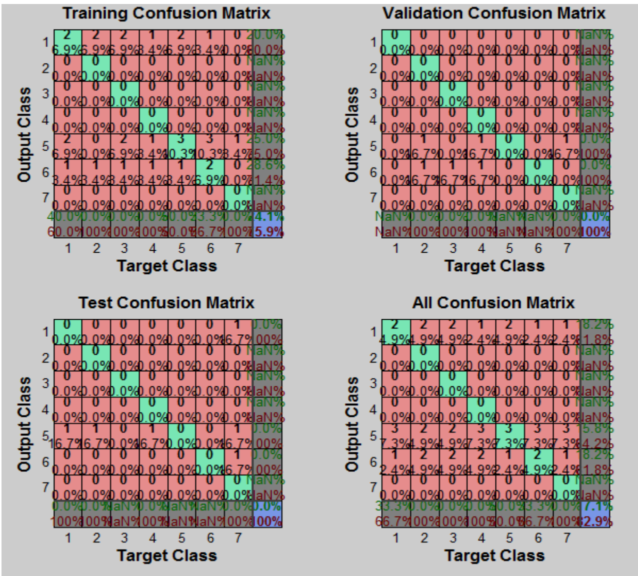


Fig. 5.28. The confusion matrix [37]

For the simulation and design of the fuzzy inference system in order to recognize cognitive-affective reactions was used the Fuzzy Inference System editing tool from the Matlab program.

The general scheme of a system proposed for the recognition of the emotional state is described in the following figure [32]:

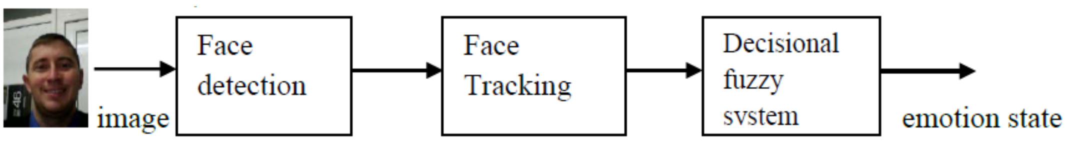


Fig. 5.31. The block structure of the facial recognition system

The decisional fuzzy system is Mamdani type and is composed of 3 components: inputs, rule base and outputs. It looks like in the Fig. 5.32 [32]. For inputs have three input variables that have the universes of discourse defined as:

• Eyelid: [40; -100];
• Eyebrow: [100;-100]:
• Mouth: [10;-100].

The associated fuzzy set of input variables are: small, moderate and large.

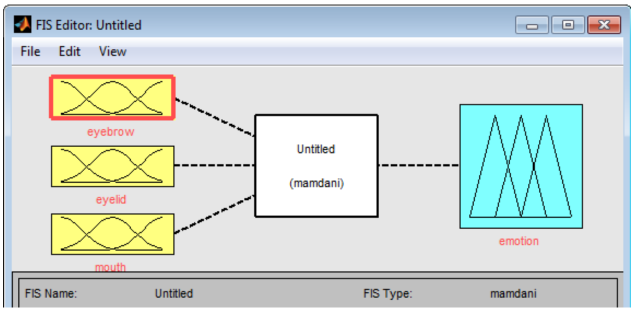


Fig. 5.32. The model of the decisional fuzzy system [32]

For the basis of rules that define six rules, one for each emotional state as follows:

- If (the mouth is moderate) and (Eyelid is small) and (Eyebrow is moderate) then (Emotion is happy);
- If (mouth is small) and (Eyelid is large) and (Eyebrow is moderate) then (Emotion is sad);
- If (Mouth is moderate) and (Eyelid is large) and (Eyebrow is small) then (Emotion is anger);
- If (Mouth is large) and (Eyelid is large) and (Eyebrow is large) then (Emotion is surprised);
- If (Mouth is moderate) and (Eyelid is large) and (Eyebrow is large) then (Emotion is fear);
- If (Mouth is small) and (Eyelid is moderate) and (Eyebrow is small) then (Emotion is disgust);

For outputs, the variable emotion has six associate emotions as fuzzy sets as follows: happy, sad, surprise, fear, anger, and disgust, each with the following universe of discussion, in order: [0;0.2], [0.2;0.4], [0.4;0.6], [0.6;0.8], [0.8;1], [1;1.2].

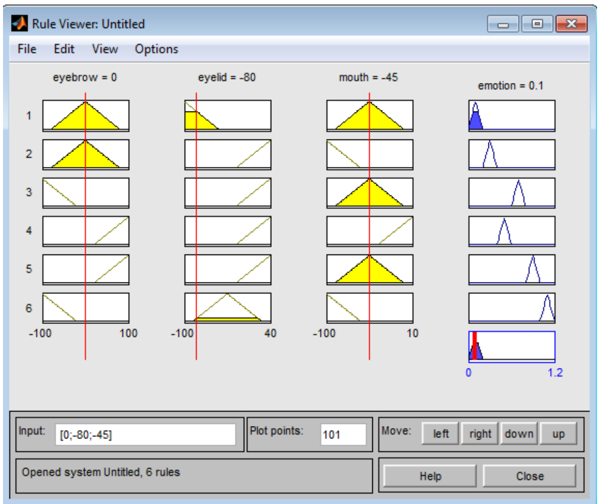


Fig. 5.33. Happiness emotional state classification by the fuzzy system decisional [32]

Figure 5.33 [32] shows the operation of the fuzzy system designed for values of input variables thus: mouth = -45; eyelid = -80; eyebrow = 0. For these values of the input variables have associated fuzzy sets: mouth is moderate; eyelid is small; eyebrow is moderate and the system decides that the emotion is happiness.

The structure of an adaptive neuro fuzzy inference system (ANFIS) is shown in Fig. 5.35 [34]. It consists of five layers: the first layer is the input variables (mouth, eyebrows, eyelids), the second layer is the membership functions of inputs, which are: small, moderate and large; the third layer is the rules system (seven in total); the fourth layer is the emotional state (also seven), and the last layer is the output system.

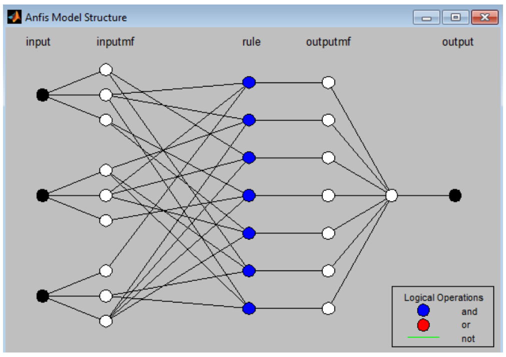


Fig. 5.35. The structure of the adaptive system

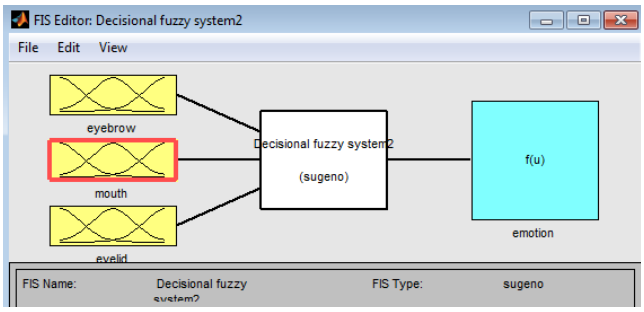


Fig. 5.36. The model of the adaptive fuzzy system

After the operations of detection and tracking human face, it is passed through a system modeled using Fuzzy Logic Toolbox from Matlab. The fuzzy model designed is Sugeno type and looks like in the Fig. 5.36. [34].

For input variables have the same universes of discussion as at the design of the fuzzy inference system.

For the output variable emotion, the universe of discussion is [0;1.4] and the associated fuzzy sets are: happy, sad, surprised, fear, anger, disgusted and neutral, each with the following universes of discussion, in order: [0;0.2], [0.2;0.4], [0.4;0.6], [0.6;0.8], [0.8;1], [1;1.2], [1.2;1.4].

For the rule base are defined 7 rules, one for each emotional state, being the same as the previous system, outside a single fuzzy rule:

- If (Mouth is small) and (Eyelid is moderate) and (Eyebrow is moderate) then (Emotion is neutral);

If we have the following values of the input variables: mouth is -45, eyelid is -100 and eyebrow is 0, then the system will decide that is respected the rule appropriate happiness state and will classify the emotion as happiness.

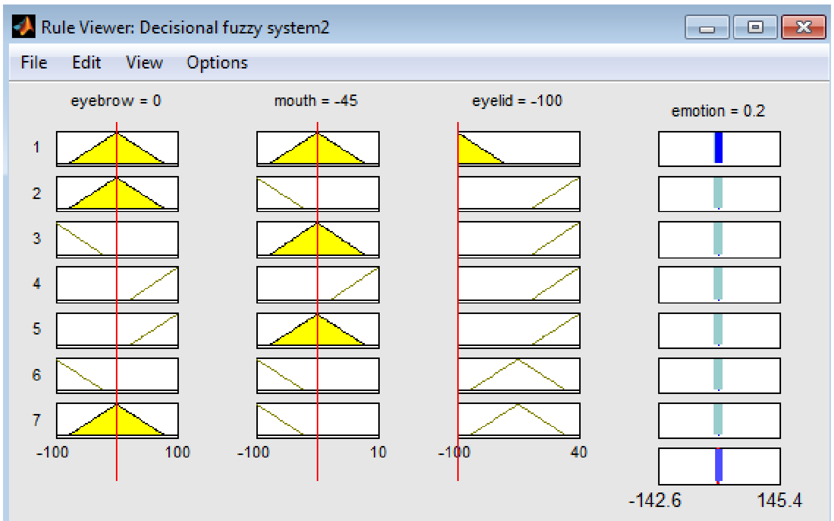


Fig. 5.37. Happiness emotional state classification by the adaptive inference system [34]

In Fig. 5.28 a), c), e) shows the graph of the training error for the 3 variables: eyebrow, eyelid and mouth, and Fig. 5.28 b), d), f) shows the graph of the points of training for the same variables (blue circles) and fuzzy system output (red asterisk).

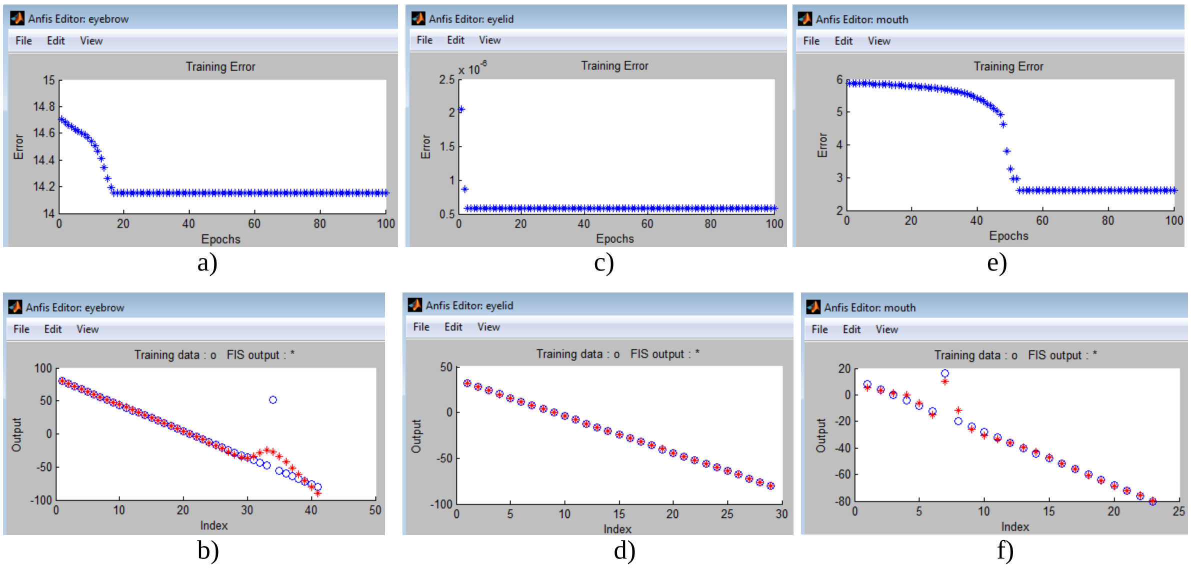


Fig. 5.38. The simulation results for the training of neuro-fuzzy inference system [34]

The simulation results obtained using the algorithm based on the SOMs network were performed in Matlab R2012b using Problem Solving Group Toolbox. Through this simulation validates that the system can group facial features for 3 input variables: eyebrow, eyelid and mouth.

The network structure is shown in figure 5.39 [33] and consists of two levels: the first level contains three input vectors, each having forty-one values, while the second level contains the SOM competitive network which consists of 100 neurons. The input vectors representing facial features, and they are: eyebrow, mouth and eyelid. The output level of network map defines a space SOMs input data on a 2D array of nodes (map grid).

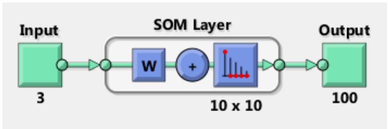


Fig. 5.39. The SOMs network structure [33]

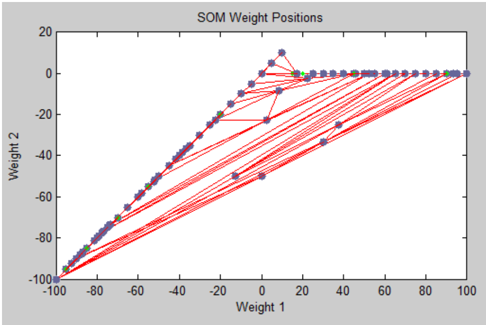


Fig. 5.45. The SOMs weight positions [33]

In Fig. 5.45 [33] is shows the plots of the input vectors as green dots and it shows how the SOMs classifies the input space by showing blue-gray dots for each neuron's weight vector and connecting neighboring neurons with red lines.

The implementation of an imitation system of the cognitive-affective states of the operator based on the algorithm SOMs was realised using the humanoid robot Elvis Alive adapted for this experiment, which is shown in figure 5.46. Its architecture contains ten engines controlled by PIC16F917 controller that allows the accurate replication of facial movements.

Fig. 5.46. The robot Elvis Alive modified structure

The role of the algorithm with the SOMs network is to provide a good group of entry points related to input variables, namely: eyebrows, mouth and eyelids, sending the results to a system of coding and conversion, the latter serving to encode the groups of entry points for each cognitive-emotional state, and then convert them into vectors. The signal is forwarded to the Arduino Leonardo board, it by programming and using the control circuits changes the expression of the Elvis Alive biomimetic platform by the actuation of the motors for each between facial components (lips, eyebrows, eyelids), according with the expression of the user. In figures 5.59 and 5.60 the experimental results with the Elvis Alive android robot are exemplified. In the first figure the imitation system shows the accurate result the cognitive-affective state of surprise , and the second figure, it is suitable to the cognitive-affective state of happiness.

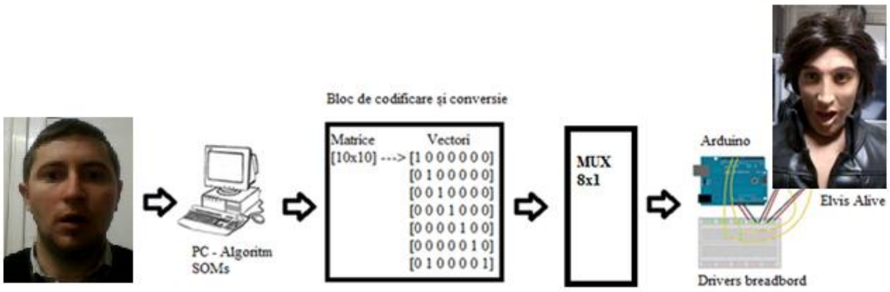


Fig. 5.59. The imitation of the ‘surprise’ cognitive-affective state using Elvis android robot

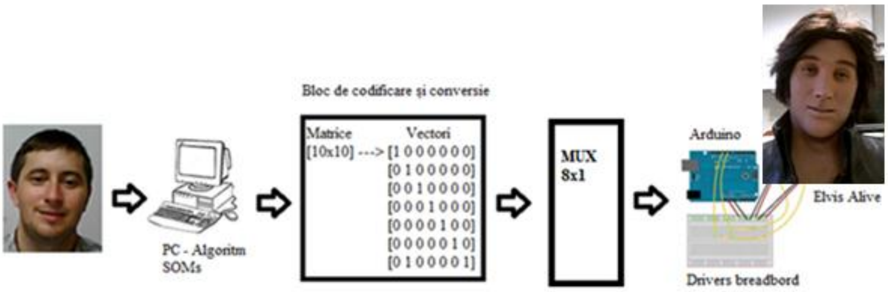


Fig. 5.60. The imitation of the ‘happiness’ cognitive-affective state using Elvis android robot

Chapter 6. Experiments with the Socibot Desktop robot

In chapter 6 experiments with the robot Sociobot Desktop and a personalization of its physiognomy are presented. For the control process of the Socibot robot using a tablet, the wireless internet connection of the two systems is realized initially.

After connecting the tablet to the wireless network and the introduction of the Socibot's IP follows connecting the robot to the network so that it can register the commends that the user will generate by using the graphical control interfaces. For example by using interface InYaFace, the user will be able to change the appearance (face, texture, affective-cognitive reactions) of the robot or change the audio settings, viewing on tablet of the images taken from the video sensors of the robot, moreover commands to run programs directly from the memory of the robot can be generated (only if the tablet has flash player installed).

Fig. 6.3. The controlling of the robot's actions using a tablet with an android system

In an initial application, a minimal behavior structure has been designed for a primary interaction with a human operator. In this application the robotic structure greets, introduces itself and discloses that it can realistically represent affective reactions. In order to complete this application, by using of the 'Compose' menu from the 'kiosk' interface a program sequence is created (presented in figure 6.4) composed of four audio files, 7 representations of the eyes, 7 representation of the appearance of the face, 3 movements of the head of the robot 7 emotional states. The result of the program sequence (lasting 8 seconds) is presented in two image captures of the Socibot Desktop robot: the first at second 3 and the second at second 4 of the program (Fig. 6.5).

Fig. 6.4. Creating sequence in the 'Compose' menu   Figure 6.5. The running on the robot

A more complex application involves using the virtual robot interface, thus enabling the robot visual programming offline and subsequently the transfer of the program (which was simulated in the virtual environment) to the Socibot robot for execution. It is shown in figure 6.9 that the designed program has a duration of 62 seconds and contains the following components: four speeches (text to speech) in English, 23 head movements and a guise for a robot. The program was created by: inserting in the timeline of the audio files created in the 'Speech' subclass, inserting the robot's movements in the library window and inserting its guise from the menu bar. Figure 6.10 exemplifies two captures resulting from the implementation of the program on the Socibot robot: the first is at the second 45 from the created sequence, and the second is at the second 53.

Fig. 6.9. The creation of the program in 'Virtual Robot'   Fig. 6.10. Running on the robot

Expressions editing and customizing the Socibot robot's physiognomy is achieved through the graphic application 'InYaFace'. The work areas of the application are shown in Figure 6.11 and they signify: creation of new facial expressions (1), inserting the name (2) configurations of the facial expression through graphic elements of the cursor type (4), saving / deleting new expressions (3). The customizing of the physiognomy will be initiated by processing performed through Adobe Photoshop, figure 6.12 [36]. This is constructed based on the model presented on the manufacturer's website [117]. The model contains a map of the accurate laying of the face within the model, the representation of internal components of the face (noted with 1) a base layer for the face (noted with 2) and the face (noted with 3), positioned in terms of order, above the 2 layers. The image created is square and must be saved as a PNG file in order to maintain the transparency of the face laying map.

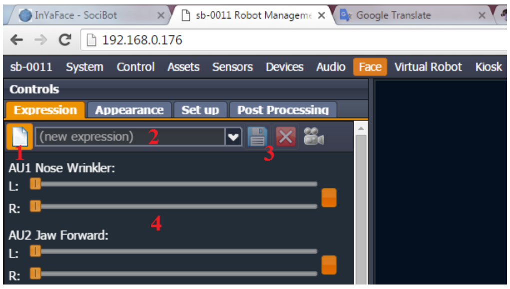


Fig. 6.11. Editing expressions in 'InYaFace'

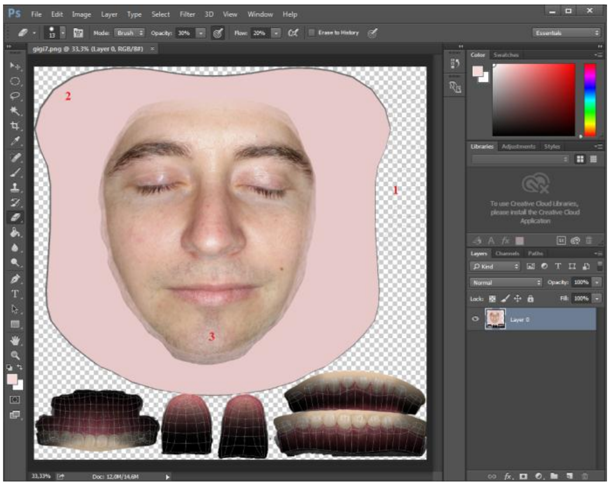


Fig. 6.12. Customizing the appearance [36]

To modify the appearance of the robot the 'Appearance' button is pressed from the 'InyaFace' app shown in Figure 6.14 [36] and the created guise is selected (noted with 1) from the drop-down list. Moreover, the eye color and their size can also be changed (noted with 2).

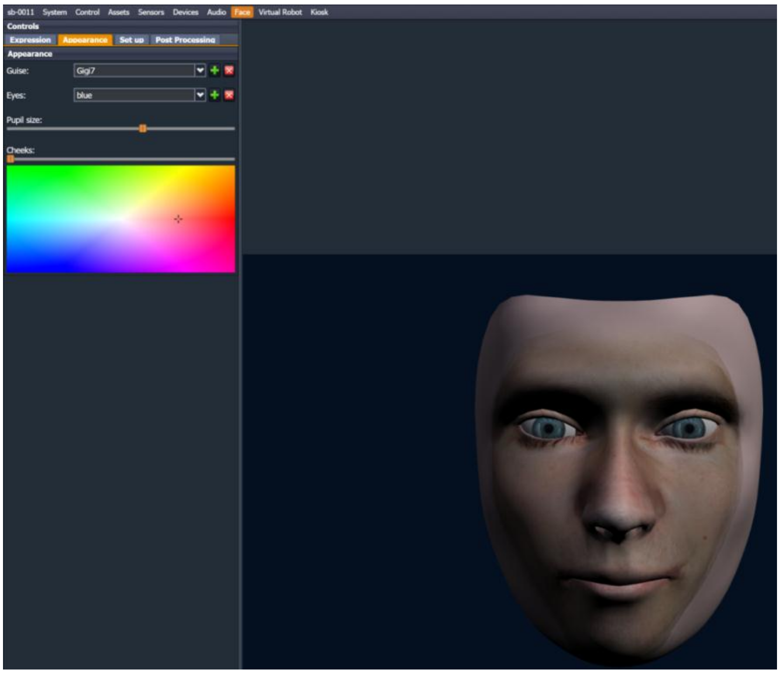


Fig. 6.14. Displaying of guise in the InYaFace [36]

Fig. 6.15. The display on the Socibot

In order to test the physiognomy customization on the Sociobot robot, two basic cognitive-affective states (happiness and sadness), implemented directly on the Socibot robot whose physiognomy was customized with the author's physiognomy, were subjected to analysis through the application based on the PCA technique, developed in Matlab. The results of implementing the program created in Matlab based on the PCA technique shown in the figures below reveals that the face recognition system based on the PCA technique uses as recognition elements the elements of the Socibot structure, which allows the misleading of the recognition application by a structure that has a humanoid robotic stucture similar to the user's physiognomy.

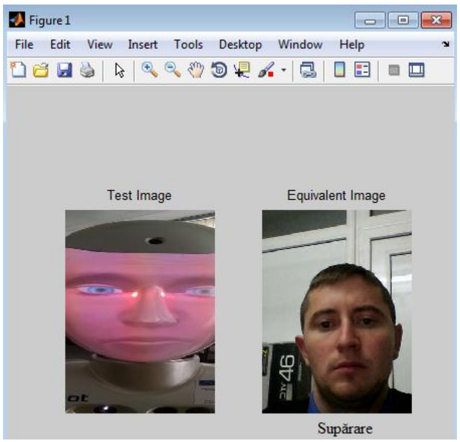


Fig. 6.16. The identification of the author from the application based on the PCA technique as being customized structure of the Socibot robot for the sadness affective state

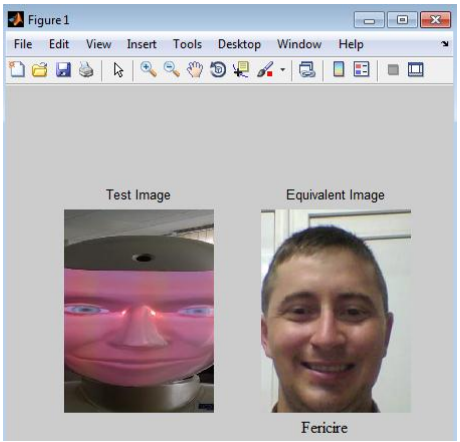


Fig. 6.17. The identification of the author from the application based on the PCA technique as being customized structure of the Socibot robot for the happiness affective state

Chapter 7. General conclusions, original contributions and future development prospects

The most important conclusions regarding the simulations, experiments and testing algorithms for the recognition of the cognitive-affective reactions are:

- The algorithm proposed by the author based on the principal component analysis technique - PCA can quickly and easily identify a person, even if his or her gaze is directed sideways at an angle of 45 °.
- The comparison between the MeanShift, CAMShift and Viola-Jones algorithms performed in this paper has revealed the superiority of the first two to the third especially where the human face is covered with an object or human parts of the same hue. The only notable advantage of the Viola Jones algorithm compared with the first two is the calculation speed.
- The application with the feedforward network projected based on the backpropagation algorithm, developed by the author, can quickly and accurately recognize 4 classes of emotions: distress, fear, anger and neutral, while for the other 3 classes: happiness, surprise and disgust some confusion appears, but they are acceptable.
- The application with the fuzzy inference system, designed by the author, can easily and quickly recognize the 6 types of emotions (happiness, sadness, anger, fear,

surprise and disgust), because it has strict rules in the data base and the member functions of the output variable are not overlaid.

- The Adaptive Neuro Fuzzy Inference System, designed by the author recognizes the 7 types of emotions (happiness, sadness, anger, fear, surprise, disgust and neutral) quickly and correctly. The lowest error is present at the eyelid input variable,however, for this input variable , the fuzzy system output can track incoming data perfectly.
- The neural network algorithm based on the self-organizing maps (soms), developed by the author, can quickly and accurately classify facial features because each point of the input vector is compared to the parameter reference vector. The eyelid input variable is best classified, having the most powerful connections between neurons of the network.

The most important conclusions regarding the experiments with the Socibot Desktop robot are:

- For the first experiment the ease of control for the Socibot robot's actions remotely, it can interact with human beings without them to realizing that the robot is controlled remotely. Moreover, there android tablet's screen there is the possibility to access information from the sensors of the robot, these using directly the interaction with the people in the operating environment.
- The second experiment shows the flexibility of the Socibot system's programming environment thus raising the possibility of running the program in the off-line environment, making corrections (if required) and then transferring and launching the robot program on the Socibot platform.
- The following experiments demonstrate the versatility of the virtual robot's programming environment in parallel to the customization of the robot's physiognomy and its speech according to user's requirements.
- In the final chapter the recognition application based on the PCA technique on the structure of the robot customized with the author's face was tested again. Tests have shown that both systems use the same physiognomy features (translated geometrically and algorithmically in the support programs) for recognition, which leads to the robot structure being classified as identical to the human operator.

The most important original theoretical contributions of the paper are listed as follows:

- Realizing a classification of the methods for face detection in 4 categories.
- Realizing a classification of the methods for the extraction of facial features.
- Realizing a classification of the recognition algorithms of cognitive-affective reactions in 10 types.
- Presenting the programming interface of the Sociobot Desktop robot.
- Designing a recognition system of the cognitive-affective reactions using the feedforward neural networks based on the backpropagation algorithm in order to classify emotional states (section 5.3).
- Designing a fuzzy inference system using the Fuzzy Inference System editing tool (FIS) for recognizing emotional states (section 5.4).
- Designing an adaptive neuro fuzzy system using the Adaptive Neuro Fuzzy Inference System tool (ANFIS) for recognizing emotional states (section 5.5).
- Designing a recognition system of the cognitive-affective reactions based on Self-Organized Maps algorithm (soms) in order to determine the appurtenance of the facial variables to the representation of the emotional states (section 5.6).
- Proposing an algorithm based on the facial action coding system (Facial Action Coding System - FACS) in order to obtain facial expressions (neutral, thoughtful, surprise, anger and joy - section 2.5).

The most important original applicative contributions of the paper are listed as follows:

- The simulation in Matlab of a recognition system of the cognitive-affective reactions using feedforward neural networks based on the backpropagation algorithm in order to classify the seven types of emotions: anger, fear, anger, happiness, surprise, disgust and neutral (section 5.3).

- The Matlab simulation of a fuzzy inference system using the Fuzzy Inference System editing tool (FIS) in order to recognize the 6 types of emotions: happiness, sadness, anger, fear, surprise and disgust. (Section 5.4).
- The Matlab simulation of an adaptive neuro-fuzzy system using the Adaptive Neuro-Fuzzy Inference System tool (ANFIS) for recognition of the 7 types of emotional states (section 5.5).
- The simulation in Matlab of a recognition system of the cognitive-affective reactions based on the Self-Organized Maps algorithm (soms) in order to determine the membership of three face variables : eyebrow, eyelid and mouth to the representation of the 7 emotional states (subsection 5.6).
- The Experimental implementation of a recognition algorithm based on the principal component analysis technique(Principal Components Analysis - PCA) in Matlab. The results confirmed the applicability performances in real-time of that application (section 5.1).
- Making a comparative experimental study in Matlab based on the use of three detection and face tracking in video sequences algorithms: the Viola-Jones, the MeanShift and the CAMShift algorithms. The comparative results highlighting the advantages and disadvantages of each algorithm relative to their use in automatic face recognition systems, to be more exact in the face detection and tracking in images subsystem (section 5.2).
- The realization of a structure based on the experimental android robot Elvis Alive WooWee modified so that facial expressions of the the proposed algorithm based on facial action coding system - FACS can be implementated. The result led to the faithful replication of 4 of the 5 basic emotions: surprise, thoughtful, joy and neutral (section 2.5).
- Making an application of the type man-machine interaction (using a tablet with an android operating system) relative to the robot's affective reactions implemented using the Socibot Desktop (paragraph 6.2.1).
- Making an application-based interface 'Kiosk' of Socibot Desktop robotic structure, by use of 5 types of files, application usable to create reactive biomimetic structures at primary level (subparagraph 6.2.2.1).
- Making an application based on the Socibot Desktop structure in order to implement a complex reactive biomimetic structure: speeches, head movements, the robot's guise, new expressions formed by modifying the facial muscles action units from the virtual robot interface (paragraph 6.2.2.2).
- The Customization of the vizual aspect of the Desktop Socibot the robot, to the author's particular features and testing the new biomimetic structures using the application developed by the author in Matlab, application based on the PCA technique (paragraph 6.3).

Selective Bibliography:

[3] B. Anderson, Fidan B., Yu C., Dirk W., UAV Formation Control: *Theory and Application, Lecture Notes in Control and Information Sciences*, Recent Advances in Learning and Control, Springer, 2007.

[4] T. Balch and Hybinette M., *Behavior based coordination of large-scale robot formations,* 4th International Conference on Multi-Agent Systems, 2000.

[12] D. Cojocaru, *Prelucrarea și recunoașterea imaginilor cu calculatorul*, Editura Repografia Universității din Craiova, Craiova, 1995.

[30] G. Gîlcă, A. C. Nicu, M. Ionescu, N. Bîzdoacă, *A brief overview of gesture control architectures*, International Journal Robotica & Management, Vol. 19, No. 2, December 2014,

ISSN 1453 – 2069, Pages 23-28, http://www.robotica-management.uem.ro/fileadmin/Robotica/2014_2/Pag_23_Gilca.pdf.
[31] G. Gîlcă, N. Bîzdoacă, *A Biometric Face Recognition System using an Algorithm Based on the Principal Component Analysis Technique*, ROBOTICA & MANAGEMENT, Editura Eftimie Murgu, Reşiţa, ISSN-L: 1453-2069, Vol. 20, No. 1, June 2015.
[32] G. Gîlcă, N. Bîzdoacă, *A fuzzy aproach for facial emotion recognition,* ACTA Universitatis Cibiniensis. Volume 67, Issue 1, Pages 195–200, ISSN (Online) 1583-7149, September 2015, http://www.degruyter.com/view/j/aucts.2015.67.issue-1/aucts-2015-0089/aucts-2015-0089.xml.
[33] G. Gîlcă, N. Bîzdoacă, *An Algorithm based on the Self-Organized Maps for the Classification of Facial Features,* ROBOTICA & MANAGEMENT, Editura Eftimie Murgu, Reşiţa, ISSN-L: 1453-2069, Vol. 20, No. 2, Pages 31-35, December 2015.
[34] G. Gîlcă, N. Bîzdoacă, *Detecting human emotions with an adaptive neuro-fuzzy inference system*, 6th International Conference ″Computational Mechanics and Virtual Engineering ″ COMEC 2015, 15-16 October 2015, Braşov, Romania.
[35] G. Gîlcă, N. Bîzdoacă, *Face Tracking System Using Camshift Algorithm*, Annals of Constantin Brancusi University of Târgu-Jiu, Engineering Series, Issue 3, Pages 40-45, ISSN 1842-4856, 2014.
[36] G. Gîlcă, N. Bîzdoacă, *Facial Expressions and Speeches Obtained Through Rear Projection using the Socibot Desktop Robot*, International Journal of Advanced Engineering and Nano Technology (IJAENT) ISSN: 2347-6389, Volume-3 Issue-2, February 2016.
[37] G. Gîlcă, N. Bîzdoacă, Lupu Cătălin, C*lassification algorithms of facial expressions by using the feedforward neural networks,* Annals of Constantin Brancusi University of Târgu-Jiu, Engineering Series, Issue 4, Pages 80-85, ISSN 1842-4856, 2015.
[58] M. Pantic, A. Pentland, A. Nijholt, and T. Huang, *Human computing and machine understanding of human behavior: A survey*, In ACM International Conference on Multimodal Interfaces, 2006.
[75] K. Scherer, T. Banziger, and E. Roesch, *A Blueprint for Affective Computing*, Oxford University Press, 2010.
[94] Z. Zeng, M. Pantic, G.I. Roisman, and T.S. Huang, *A survey of affect recognition methods: Audio, visual, and spontaneous expressions,* IEEE Transactions on Pattern Analysis and Machine Intelligence, 31:39-58, 2009.