Biometrics of Asymmetrical Face

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Abstract. Traditionally, in face authentication/identification methods the presumption concerning face/head symmetry is used, which is logical in terms of the next qualitative reduction of primary data to templates as well as not using the primary face images, for example, in advanced applications that concern creating techniques by means of which it is possible to reproduce the extraordinary complexity of skin, muscle, eye and hair movements that convey emotion, gesture, psychological state or in psycho-sociological applications. In the paper, new research direction called *Biometrics of Asymmetrical Face* is presented. Apart from the direct study of new biometric techniques types in traditional sense, the essential new problem in this direction is the ability of interpretation of untapped "subtle" primary face information in psychological constructs terms, for example, person's cognition-psyche characteristics and integrated usage as biometrics in traditional understanding as well as psychological constructs. The new direction study is based on modern knowledge of face authentication/identification, functional brain asymmetry phenomena and ophthalmogeometry, knowledge of psychological testing of personnel types. This is an example of collective interpretation of physiological-behavioral biometrics and psychological constructs. The study is stimulated with modern interdisciplinary needs for human science development.

In the paper, specifically, it is presented a new type of precise normalized model of a face called *Czestochowa-face*, in the sense suiting the specification of the problem of modern and prospect person's authentication/identification techniques creation in biometrics. As soon as two new biometric techniques based on the Czestochowa-faces are created; the ophthalmogeometrical technique and the face asymmetry one will be partially researched. Also, attention has been drawn to interdisciplinary research context.

The main developed original components of the techniques are the following: 1) A procedure of finding (discovering) a „truthful" vertical axis of a face. 2) A procedure of 2D normalization of a single frontal view of a face image using a unit called *Muld.* 3) A procedure of constructing a combine (two polar and one Cartesian) facial coordinate system based on the "truthful" vertical axis and a special virtual coordinate system for eyes area. 4) An algorithm of person's ophthalmologic pattern visualization in the virtual coordinate system. 5) An algorithm of the synthesis of special facial pictures (left-left and right-right composites) for face asymmetry features evaluation. 6) An algorithm of the Czestochowa-face creation. 7) An algorithm of precise mapping and evaluating (the pseudo-information) similarity of a pair of compared facial elements or given element set in a holistic manner. 8) Some theses concerning the cognition-psyche and interdisciplinary interpretation of gained ophthalmogeometrical, face asymmetry and other information features. 9) (A procedure of special linear oversampling a part of a picture if the picture has low resolution.)

Beside the first-hand usage, the new techniques may be employed in the areas of human-computer interaction, identification of cognition-psyche type of personality for personnel management, advanced education, and so on.

Key words. Face asymmetry biometric, Ophthalmogeometrical biometric, Person's cognition-psyche type identification, Information theoretic measure, Future biometric system.

1. Background and problem statement

On the basis of the analysis of the state of development of modern person autentication/identification techniques based on facial information [1-5, 15, 31] there may be drawn a conclusion that they cannot be significantly improved in the sense of identification errors reduction, especially with the use of large data bases. Even utilization of such advanced methods as Wavelet transformation, ICA, SVM, fusion of biometrics is of efficiency [31]. The enumerated techniques also cannot operate effectively and in advanced applications where „precise and subtle" primary face information should be used. These are, for example, psychological testing applications, emotion and gesture simulation, implementation of person's unique behavioral patterns into virtual humans. (The work is still in its infancy.)

There are many known reasons that delimit potential identification errors value: change of illumination, face kinematics, emotional states, and so on. However, in author's opinion, one of the main reasons of this situation lies in the assumption that face/head has symmetrical form [25, 15]. Metaphorically, identification procedure in described situation may be compared to „searching for the black kitten in the dark room when the kitten is already not there". Author's estimation of the effect from the asymmetric face model implementation indicates that the error of absolute values of primary face traits measurements can be reduced to 5-7%.

The phenomena of face asymmetry and functional brain hemispheres asymmetry have been known for long [18, 17, 19, 8, 7, 9, 10]. However, the productive link of two phenomena accomplished for the first time in psychological personality types diagnosing method which was compiled by professor Avtandil Anuashvili (psychologist, physicist) [12]. The method is based on the thesis that face is an informational background projecting in biological and psychological terms the results of joint brain hemispheres functioning which, to a large degree, has characteristic birth traits. This method allows *instrumental* diagnosing of 49 types of ordinary people in coordinates „left-side thinker – right- side thinker ", „psychologically stable personality - destable personality".

Ophthalmogeometry phenomenon has been discovered by prof. Ernst Muldashev (ophthalmologist) lately [11]. Apart from other interesting facts, E. Muldashev has established that after 4-5 years from birth the only *almost absolutely constant j* of human body is the diameter the transparent part of cornea which equals 10±0,56 mm. He also presented an idea that there is also a unique for every men ophthalmogeometrical pattern of eyes area and of a face.

The primary information of the enumerated phenomena is presented by means of 2D single image of a face of ordinary quality. Biometric and/or cognition-psyche features of a person may be drawn out of this information in a non-intrusive way. The aim of this paper is to verify the thesis that the effects of face asymmetry and ophthalmogeometry may serve as new very valuable biometrics especially in case of their fusion. Moreover, it should be verified whether these biometrics contain information about cognitive and psychological features of a person which can make them be interesting for future applications [31, 29, 30, 20, 21, 24]. The paper may be qualified as an exploring new research direction.

2. On face asymmetry and brain asymmetry phenomena

The serious research of thinking mechanisms and psyche may be done only on the basis of usage and transdisciplinary interpretation of information (rather knowledge) metabolism principle. As proven in practice, the information approach of C.. Jung for creating typology of personality, based on a person perception and decision procedures properties, has been the most productive one (above 17000 scientific works on this theme; well-known I. Myers-K.Briggs's person typology [13]).. However, then (C. Jung's time) the phenomenon of brain asymmetry was not yet known. And now the knowledge of asymmetry of the functions of brain hemispheres [8, 7] is practically not used [2-5]. Many scientists use the term „left-, and right-hemisphere thinker" or „left-, right-brained thinker" [14] on the non-formal (metaphorical, everyday usage) level.

Nonetheless, a more productive, synergic and effective thinking or research team may be synthesized in the manner illustrated by the SCI-Conference metaphor [25, 27-30]: "We are trying to relate the analytic thinking required in focused conference sessions, to the synthetic thinking, required for analogy generation, which call for multi-focus domain and divergent thinking. We are trying to promote a synergetic relation between analytically and synthetically oriented minds, as it is found between left and right brain hemispheres, by means of *corpus callosum*, trying to bridge analytically with synthetically oriented efforts, convergent with divergent thinkers and focused specialists with non-focused or multi-focused generalists". (The SCI-Conferences are yearly organized by the International Institute of Informatics and Systemics, Orlando, Florida, USA. The materials are available at http://www.iiis.org/sci2003)

Face asymmetry phenomenon has been known for long and researched by painters, psychologists and other specialists of this kind [17-19]. However, in live biometrics, psychological testing, human resources management, the phenomenon is not widely used. At the moment, the interesting interpretation of face asymmetry is based on the technical and/or psychological formalization of the brain hemispheres asymmetry phenomenon, being dealt with in [12].

The idea of face asymmetry phenomenon usage as biometrics came to author's mind while getting familiarized with [7] in New York in March 2002. It's first presentation with the slide session was realized by the author during the oral presentations [24]. The materials [12, 16] were found in Internet later on. In this article the connected model, algorithmic and some developmental procedures concerning both techniques are presented.

At the moment, two *quantitative* approaches to the face asymmetry phenomenon usage has been presented: 1) the direction [16] that is based on the traditional biometric methods (and are contained some methodological inaccuracies), and 2) A. Anuashvili's oryginal hypothesis and method [12] that is based on the author's original wave model of the brain hemispheres asymmetry functioning and some new hypotheses.

According to Anuashvili's interpretation [13], human being possesses two bases: 1) spirit, intuition (***I***) - principles of life (things obtained by man from nature – from God and from his ancestors, and 2) mind, logic (***L***) - personal manifestations in real life at a certain moment. To fulfill the purpose of life that consists of a creative spirit and vital energy for the future, it is necessary to achieve harmony (***H***) between these two bases. If the harmony of the spirit and mind is disturbed (***D***), there appears dissoluteness either in mind or spirit. If the harmony of the spirit and mind is not disturbed, a man is in a stable (***S***) state. The concrete type is identified by a set of parameters in coordinates {***I-L, S-D***}. (Some reviewers consider that the method is speculative.)

The brain functioning model has been constructed as a model of a dynamic system, in which two coherent harmonic processes exist. In Anuashvili's opinion, these can simulate a cooperative work of two hemispheres. A difference ($\boldsymbol{\Delta A}$) of the two harmonic process amplitudes and a coefficient of coherence (***C***) are the outputs of the model. A coefficient harmony (***H***) of a personality is calculated. Two hemispheres accomplish quite different functions: the right hemisphere is responsible for intuition (spirit), while the left one is responsible for logic (mind). Anuashvili has ascertained that the cerebral asymmetry is displayed on a person's face in quite a definite manner (**!**?). On this base, two new images - person's face composites, may be synthesized. The first image – called *spiritual* portrait - reveals spirit, intuition, principles of life (i.e. things given to the human beings by nature). The second image – called *life* portrait – reveals the mind, logic, and personal manifestation in real life at the moment. On the basis of information which is included in the portraits Anuashvili's type of personality is identified by means of an original (!**?**) algorithm. A validation procedure for the method can be executed on the basis of person's encephalogram measuring.

Main advantage of Anuashvili's method is that it is one of the primary *instrumental* psychological methods concerning the examination and usage of brain asymmetry phenomena and face asymmetry in various modern applications. Besides, some examples of personality type identification by means of the Anuashvili's method will be used in our work to verify the results gained on the basis of pictures processing taking into consideration the face asymmetry fearures and the ophthalmogeometrical pattern (see, for example, thesis about using the point 3 of the ophalmogeometrical pattern as an indicator of the prevailing hemisphere properties).

3. On the ophthalmogeometry phenomenon

According to E. Muldashev [11], person's psychological and other states are described with 22 parameters of an eyes part of face (Fig.2). We use information that is included in some planar ophthalmogeometrical figures, which are produced with tangents of four eye corners, appropriate eye silhouettes, wrinkles over eyes, and some other facial components.

4. Partial rich in content and algorithmic problems to be solved

The issue analysis has shown that, to achieve the aim, numerous necessary mutually connected problems should be solved, and adequate algorithmic examination tools should be created. These are:

1) A procedure of finding (discovering) a „truthful" vertical axis of a face.

2) A procedure of 2D normalization of a single frontal view of a face image using a unit called the *Muld.*

3) A procedure of constructing a combine (two polar and one Cartesian) facial coordinate system based on the "truthful" vertical axis and a special virtual coordinate system for eyes area.

4) An algorithm of person's ophthalmologic pattern visualization in the virtual coordinate system.

5) An algorithm of the synthesis of special facial pictures (left-left and right-right composites) for face asymmetry features evaluation.

6) An algorithm of the Czestochowa-face creation.

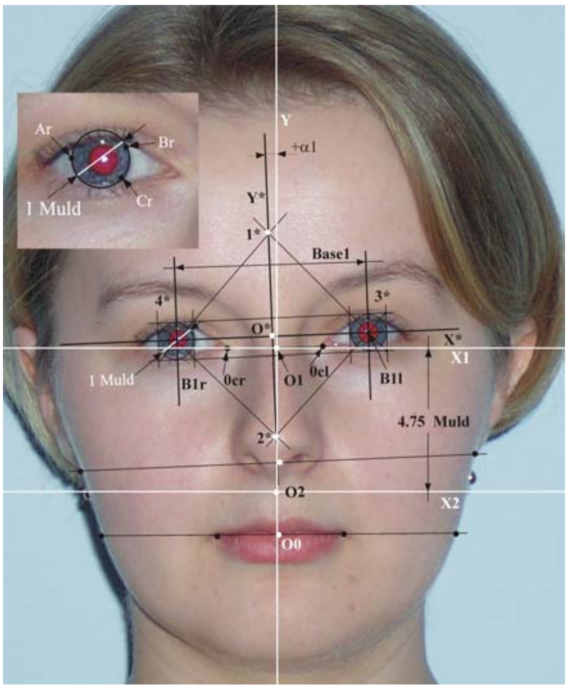
7) An algorithm of precise mapping and evaluating (the pseudo-information) similarity of a pair of compared facial components or given component set in a holistic manner.

8) Some theses concerning the cognition-psyche and interdisciplinary interpretation of gained ophthalmogeometrical, face asymmetry and other information features.

9) (A procedure of special linear oversampling of a part of a picture if the picture has low resolution.)

5. „Truthful" vertical axis, *Muld*-normalization, two special coordinate systems of a face

Human face is an example of the new class of information objects– non-rigid, dynamic, intelligent ones, mathematic or algorithmic description of which is an art and challenge for programmers. In the course experiments for finding „real" vertical face axis, there were chosen anthropometrics points ***O1*** (the center of a line linking interior eye corners *0cr, 0cl* in Fig.1 or points 8^* and 6* in Fig.2) and ***O0*** (the center of a line linking mouth corners in Fig.1). (In the case of the assignation of point *O0* being impossible this way , there has been also a reserve version of the procedure.)



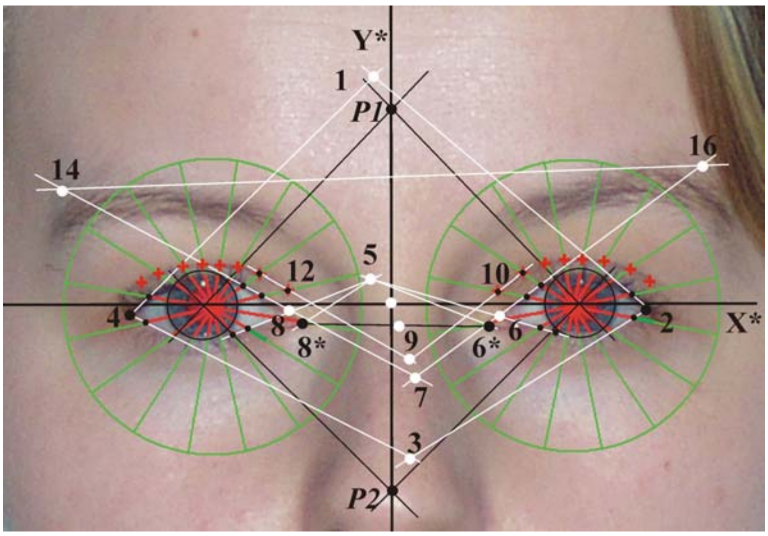


Fig.1 and **2** Illustration of the preparatory and content-related stages of an ophthalmogeometrical pattern estimation accordingly.

(The normalizing unit called 1 *Muld* equals 10±0,56 × 10±0,56 mm and for current scale of the image estimates as ***?N*** pixels.)

The sequence of calculating steps for determining a „truthful" vertical axis *Y* of a face image and the special coordinate system *Y-O1-X1-O2-X2* creation is as follows.

INPUT: An person's input image, 1 *Muld* value evaluated in ***?N*** pixels.

OUTPUT: The special coordinate systems *Y-O1-X1-O2-X2* (Fig.25-26) marked in *Muld*s.

Step **1**. Calculate the placement of the points *O1* (Fig.1).

Step **2**. Calculate an auxiliary points *O0* – the second original point of „truthful" vertical axis *Y* (Fig. 1) and visualize the vertical axis *Y*. (The reserve variant of finding a point functioning as *O0* has also been described.)

Step **3**. Build and mark a coordinate system *Y-O1-X1-O2-X2*. (Distance *O1-O2* equals 4,75 *Muld*s. Axes *X1* and *X2* are the lines perpendicular to *Y* in points *O1* and *O0* respectively.)

For strict mapping and/or face components comparison (silhouette, eyes, brows, mouth, nose, ears, wrinkles of different kind, unique traits) uses necessary quantity of rays coming form points *O1* and/or *O2* whole face coordinates system , as well as the necessary quantity of parallels to *Y* and/or *X1* lines. All measurements *here and below* are done in *Mulds*.

The sequence of calculating steps for determining a special virtual coordinate system Y^*-O^*-X^* for eyes area and its adjustment to the coordinate system *Y-O1-X1-O2-X2* is as follows.

INPUT: Person's input image; the coordinate system *Y-O1-X1-O2-X2* marked in *Muld*s value.

OUTPUT: The coordinate system Y^*-O^*-X^* marked in *Muld*s; two adjusted coordinate systems. (Systems adjustment parameters (α angle, O^*-*O1* vector).

Step **1**. Find a circle corresponding to the cornea edges for the right eye (points Ar, Br, Cr – Fig.1); repeat analogically for the left eye.

Step **2**. Build and mark a coordinate system Y^*-O^*-X^* (Fig.1).

Step **3**. Build auxiliary square 1^*-3^*-2^*-4^*. If points 1^* and 2^* square 1^*-3^*-2^*-4^* are on the *Y* axis* then

Step **4**. Mark in *Muld*s the system Y^*-O^*-X^* , adjust the two systems, and measure angle *α1*, vector O^*-*O1*.

6. Ophthalmogeometrical pattern visualization and composite synthesis

As proven below, the ophthalmogeometrical pattern has a unique appearance from birth till human death. But it is not ordinary visible. Examples of ophthalmogeometrical pattern are given in Fig.2, 13-17, 18, 20, 22.

The sequence of calculating steps is as follows.

INPUT: A 2D single frontal view facial image; the coordinate systems *Y-O1-X1-O2-X2* and Y^*-O^*-X^* marked in *Muld*s.

OUTPUT: Person's ophthalmogeometrical pattern (Fig.2, 13-17, 18, 20, 22).

Step **1**. Find the placement of circles described around the eyes cornea (iris) and measure the amount of pixels that constitutes 1 *Muld* (Fig.1).

Step **2**. Build a coordinate system Y^*-O^*-X^* and the figure 1^*,2^*,3^*,4*. If points 1* and 3* are placed on the *Y** line, ***then***

Step **3**. Measure the Base 1 and forget in *Mulds* the primary ophthalmologic pattern.

Step **4**. Build the external figures 1,2,3,4 and internal – 5,6,7,8, the triangles 5,8,8* and 5,6,6*, 3,14,15, the angle 10,9,12 (Fig.2).

Step **5**. Find point *O1*. Find the coordinate system *Y-O1-X1-O2-X2*.

Step **7**. Adjust the system Y^*-O^*-X^* and system *Y-O1-X1-O2-X2* as in Fig.1.

Step **8**. Measure the ophthalmogeometrical parameters in *Mulds*:

$$[\ \pm \boldsymbol{xo1}^*, \pm \boldsymbol{yo1}^*;\ \pm \boldsymbol{\alpha 1};\ \boldsymbol{B1} \uparrow \boldsymbol{x3}^*, \boldsymbol{y3}^*, \pm\%\boldsymbol{\Delta x3}^* \uparrow \boldsymbol{x1}^*, \boldsymbol{y1}^*, \%\boldsymbol{\Delta y1}^*, \boldsymbol{y15}^* \uparrow \boldsymbol{x5}^*, \boldsymbol{y5}^* \uparrow \boldsymbol{x7}^*, \boldsymbol{y7}^* \uparrow \boldsymbol{x9}^*, \boldsymbol{y9}^*\ ] \qquad (1).$$

Vector (1) that has 17 main ophthalmogeometrical parameters was divided in 6 parameter subsets. An arbitrary parameter as well as a subset has a concrete interpretation in biometric or cognition-psyche terms.

In Fig.3-6, example of facial composite synthesis procedure. The composite is an input information for face asymmetry features analysis. In Fig.7, the grandmother, mother and daughter's ophthalmogeometrical patterns are presented; as can see, the pattern is an *unique* person biometric.

Fig.3-6 Results of calculating "truthful" vertical axis *Y* and synthesized *NI*-, MI-, LC-, RC-images (natural and mirrored images; left/left and right/right composites)

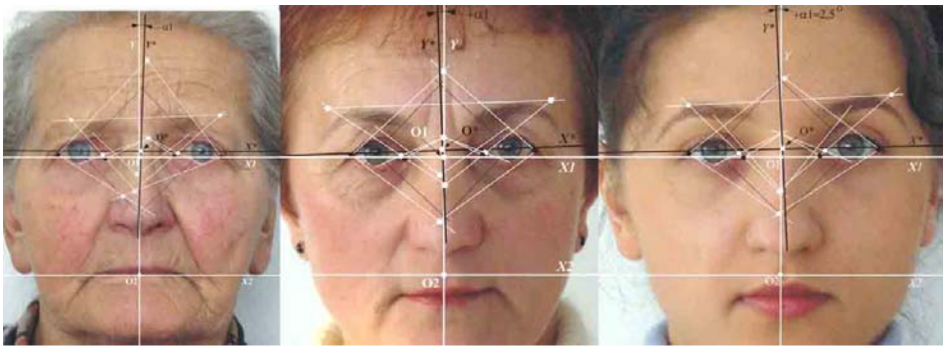


Fig.7 Example of the normalized ophthalmologic patterns for grandmother (84 years old), mother (53), and daughter (24)

7. Aging stability and uniqueness of an ophthalmogeometrical pattern

In Fig.8-17 and 18-23, photos and appropriate ophthalmogeometrical patterns for personality 1 (young man) and personality 2 (young woman) in different ages, including 4-5 years old period. Even on a base of quantitative inference it may be notice uniqueness and practical invariability of the pattern if some serious psychological or somatic disease have not been happened.

Estimators of mean variations of vector (1) main parameters, during parameter comparison of any pair person's ages, fluctuate in the range 2-5%. Also, conclusion about necessity of the parameter B1 normalization has been done.

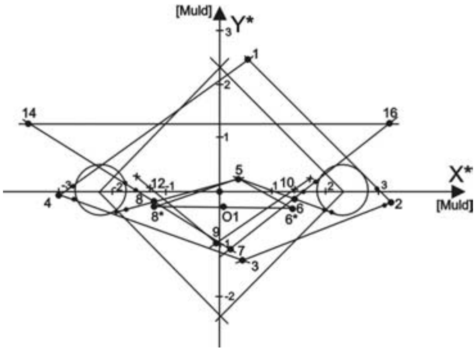
5 years old

10 years old

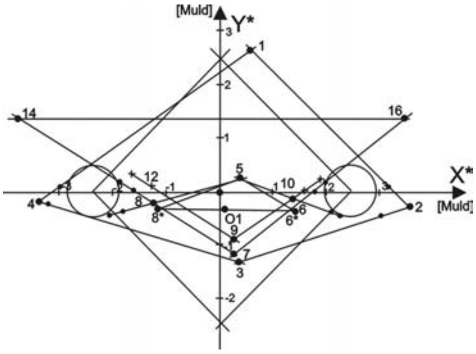
15 years old

20 years old

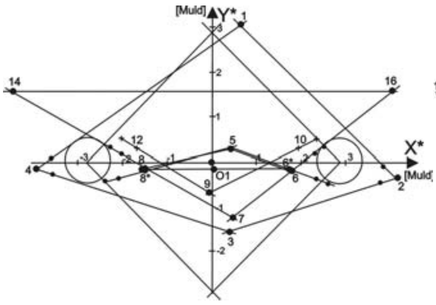
25 years old



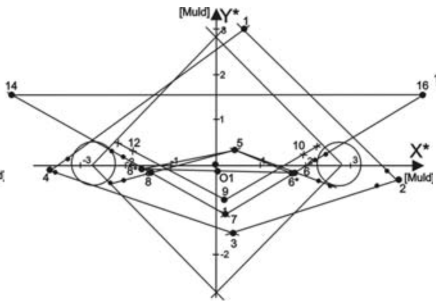
5 years old



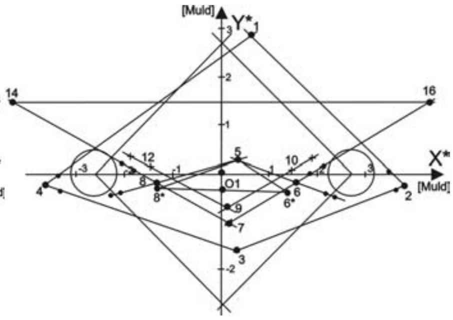
10 years old



15 years old



20 years old

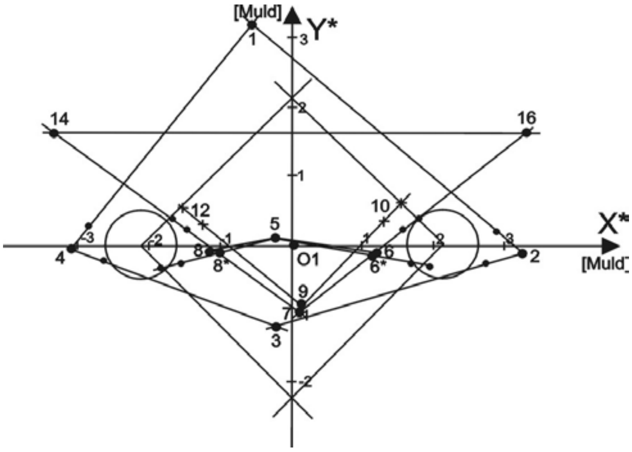


25 years old

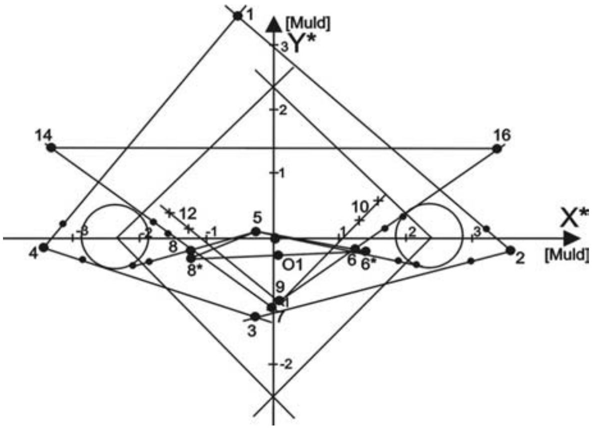
Fig.8-12 and **13-17** Accordingly, photos and visualized ophthalmogeometrical patterns of person 1 for different age (5, 10, 15, 20, 25)

To research of the ophthalmogeometrical pattern properties, a special data base containing photos of 150 students, their near relations and friends as well as program system FACE_ASYMMETRY were created. Ophthalmogeometrical patterns were visualized and normalized. Vector (1) parameters were also measured.

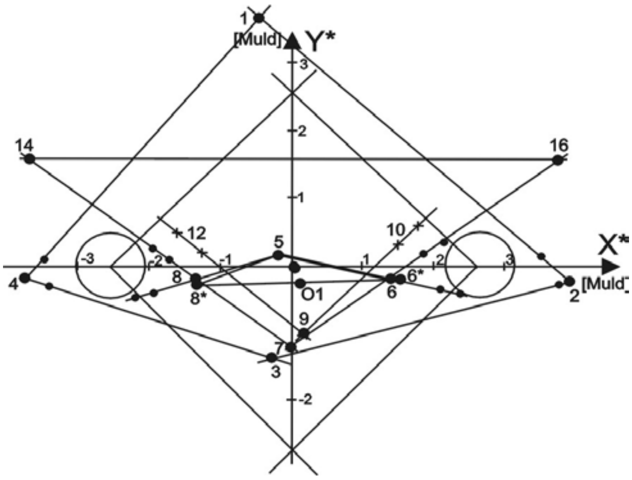
Because the vector (1) elements have concrete (hypothetical for the present) interpretation in cognition-psyche terms, the identification procedure is facilitated. Pattern clasterisation procedure may be executed using a special “+ or –“ mask for parameters. Only at the procedure end it is necessary used statistical processing and complex decision making. Comparable with other biometric techniques result may be achieved without some visible efforts.



(**2** years old ↑)



(**9**) ↑)



(**24**) ↑)

Fig.18-23 Accordingly, visualized ophthalmogeometrical patterns and photos of person 2 for different age (2, 9, 24 years old)

8. On pseudo-information similarity of a pair of information objects in holistic manner

Main procedure of any biometric technique is the measuring of meaningful similarity of two information objects. Traditional mathematical measures [6] of nearness are not adequate to any psycho-physiologic or cognition measures that are used by human being. The fundamental reason for the existence of such situation is connected with the phenomenon that the well-known Weber-Fechner law describes. A human being perceives images into psycho-physiological space, but not physical one, and in a holistic manner, but not in an algorithmic one.

In [22, 23, 26], it was proved that the pseudo-information measure (2) is an effective tool for a holistic similarity evaluation and the measure advantages were presented. The functional for the measure (2), which is used in the paper, presents below.

$$\pm JeK^{(\Sigma)}\ [PDF(\sum_{z=1}^{Z} F_i^{(Z)}); PDF(\sum_{z=1}^{Z} L_{i\pm(\otimes:p,r,...)}^{(Z)})] = \frac{\sum_{i,z,(i\pm...)} [f_i^{(z)} - l_{i(\pm...)}^{(z)}] \log_2 [f_i^{(z)} / l_{i(\pm...)}^{(z)}]}{-\sum_{i,z} f_i^{(z)} \log_2 f_i^{(z)} - \sum_{i,z,(i\pm...)} l_{i(\pm...)}^{(z)} \log_2 l_{i(\pm...)}^{(z)}} 100 \qquad (2)$$

where: $F_i = f\{f_1,...,f_I\}$, $L_i = \{l_1,...,l_I\}$ – basic (*F*) and comparing (*L*) functions (for example, sample sequences or images, correlation or other functions, *pdf*s (a probability density function), etc.) that answer requirements of *pdf*; *I, i=1,…,I* – grid, on which values of the functions *F, L* are formed; *Z, z=1,…,Z* – a number of comparing objects components (for example, five components in Fig.26); $i(\pm(\otimes:p,r,...))$ - 1D (for *i*), 2D (for *i, p*) displacement in grid's steps for *L* function relatively basic function *F* while fitting an optimal common places of two objects: (right - (+), left - (-); ±*JeK* – the sign that identifies a situation, when a default basic function is *F* – (+), and, on the contrary - (-).

In the numerators of Eq. (2), the functionals for G. Jeffrey's divergences are placed. Shannon's entropies of suitable functions *F* and *L* are used in the denominators. Peculiarities of the measures are described in [22, 23, 26]. In an area of little deviations, the *JeK* values may be described by a linearized function and interpreted as cybernetic similarity of complex information objects. The usage of the logarithmic function, to some degree, conforms psycho-physiological properties of human reception (Weber-Fechner law).

To generalize the content of statistical information notions such as entropy, information, divergence to non-probabilistic cases, the two compared functions *F(.)* and *L(.)*, which may have any nature, must possess formal properties of a traditional *pdf*. This means that the functions *F(.)* and *L(.)* must be normalized under the mentioned demands (marked as *PDF[F], PDF[L]*). Then, contents of statistical information notions are preserved and common interpretation may be expanded to any nature functions. Furthermore, mathematical and rich in content complications may be avoided.

An advantage of the measure (2) is the fact that *PDF[.]*-function can describe the whole object or set of its components. In Eq. (2), the mentioned *PDF*-function vectors have been combined by *Z* suitable vector components. If the vector of components are independent, then an additive property of the measure is guaranteed by using the logarithmic function.

By means of the measure (2), it is possible to evaluate cybernetic similarity of two objects of any nature that are considered both monolith objects, and objects consisting of its components (see Fig.27). G. Jeffrey's divergence is used in constructions of the measure as the basic element. However, the areas of usage, content, context and properties of the divergence are expanded and improved essentially.

The main problem of an application of Eq. (2) concerns the art of content-related and exact *F* and *L* vectors extraction.

9. Example of mapping and similarity evaluating facial silhouettes

In Fig. 25-26, the result of the *Muld*-normalization and mapping two facial (woman's and man's) images for *F -, L-* vector extraction and similarity evaluation (see Eq.(2)) of the facial silhouettes is given. Dashed mapping lines are used to indicate not visible (fictive) silhouette points.

The woman's and man's facial images in Fig.24-25 have been represented in a form called *Czestochowa-face*, that is

1) After carrying out the special normalization in 1 *Muld* scale (the value of cornea diameter is the only known constant of human body after 4-5 years)
2) Taking into consideration the latest discoveries of the ophthalmogeometry, face asymmetry, and brain asymmetry phenomena and problem of the listed phenomena interpretation in live biometrics issues, psychological testing, and so on
3) Presenting the possibility of exact facial image mapping and/or its proper component set in the uniformed *absolute* measure values.
4) Enabling the algorithmic (automatic) execution of measurement and comparing procedures.

Examples of *Czestochowa-faces*

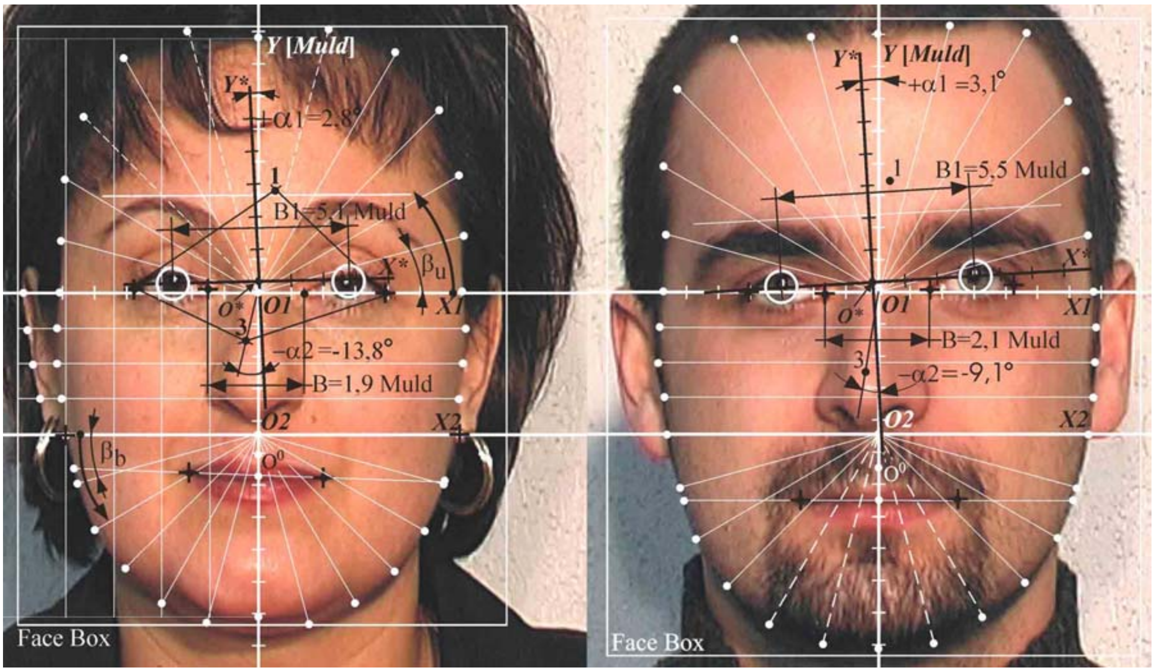


Fig. 24-25 Illustration of the *Muld*-normalization and mapping procedures. Woman's and man's facial images are mapped for *F-, L-* vector extraction and similarity evaluation of the facial silhouettes

The main Czestochowa-faces feature are: 1) the truthful vertical axis *Y* of an asymmetrical face, 2) the special combined system *Y-O1-X1-O2-X2* and adjusted to it the special coordinate system Y^*-O^*-X^* for eyes area of a face, 3) the 2D *Muld*-normalization procedure and construction of "Face Box", 4) the ophthalmogeometrical pattern of a person, face asymmetry feature, and brain asymmetry phenomenon background, 5) procedure of precise evaluating of (pseudo-information) similarity for any pair of facial components, sets of components, and faces, 6) algorithmic realization of the model, 7) measured features interpretation in biometrics, brain asymmetry, and cognition-psyche terms.

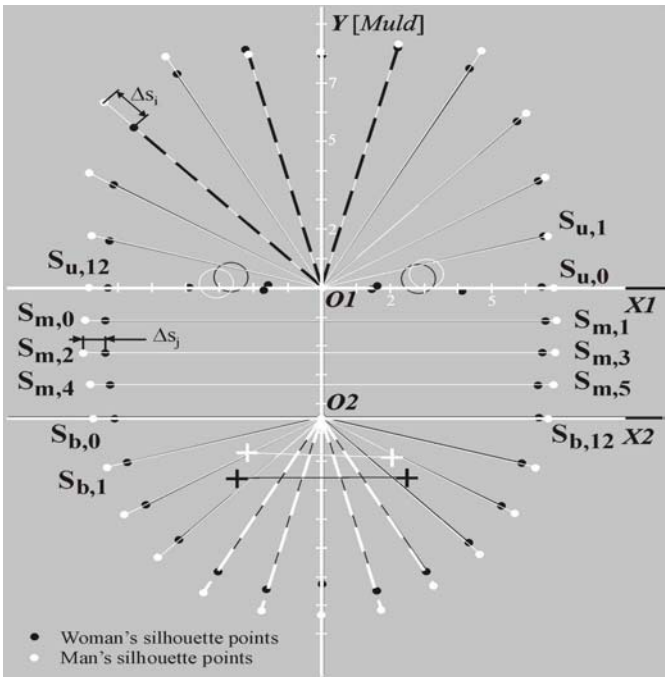


Fig. 26 Scheme of *F-, L*-vector extraction for similarity evaluation of woman's and man's facial silhouettes

Tab.1. Estimators of the *F*-, *L*-vectors and pseudo-information similarity for silhouettes of the woman's and man's faces (Fig.24-25)

	Facial silhouette vector values [*Muld*]			**Facial silhouette vector values [*Muld*]**	
	F (wom.)	***L*** (man)		***F*** (wom.)	***L*** (man)
$S_{u,0}$	6,553	6,852	$S_{m,3}$	6,580	6,895
$S_{u,1}$	6,847	6,936	$S_{m,4}$	6,350	6,866
$S_{u,2}$	7,402	7,640	$S_{m,5}$	6,418	6,823
$S_{u,3}$	8,236	8,553	$S_{b,0}$	6,188	6,794
$S_{u,4}$	8,824	9,458	$S_{b,1}$	6,021	6,543
$S_{u,5}$	8,659	8,730	$S_{b,2}$	6,062	6,714
$S_{u,6}$	8,147	8,170	$S_{b,3}$	6,000	6,801
$S_{u,7}$	8,627	8,363	$S_{b,4}$	6,227	6,975
$S_{u,8}$	8,593	9,198	$S_{b,5}$	6,199	6,908
$S_{u,9}$	7,873	9,127	$S_{b,6}$	5,837	6,808
$S_{u,10}$	7,158	7,969	$S_{b,7}$	6,240	6,863
$S_{u,11}$	6,535	7,080	$S_{b,8}$	6,283	6,696
$S_{u,12}$	6,337	6,910	$S_{b,9}$	6,200	6,668
$S_{m,0}$	6,485	6,997	$S_{b,10}$	6,160	6,594
$S_{m,1}$	6,621	6,939	$S_{b,11}$	6,153	6,575
$S_{m,2}$	6,472	7,069	$S_{b,12}$	6,472	6,722
	Feature is not visible			***JeK* = - 0,0927**	

In Fig.26, a scheme of *F-, L*-vector extraction for similarity evaluation of woman's and man's facial silhouettes (see Fig.24-25) is presented. In Table 1, a result of calculating facial silhouettes pseudo-information similarity value is given*: JeK* = - 0,0927. Negative sign of the *JeK* value means that *F*-function into Eq. (2) is the vector describing the woman's face silhouette.

Values of pseudo-information similarity for the pairs of *NI*-face and MI-face, LC-face and RC-face silhouettes (see Fig.3-6) are given in Table 2.

Tab. 2. Estimators of the pseudo-information similarity for silhouettes of the different types of woman's and man's faces

±*JeK(.)*[%]	*NI*-MI	*NI*-LC	*NI*-RC	LC-RC
Woman face (**Fig.1-4**)	0,0394	-0,0170	0,1525	0,2070
Man face (**Fig.26**)	0,0334	0,3578	0,1486	-0,1193

Analyzing the face asymmetry measuring result (Tables 1 and 2), it is worth paying attention to very high sensitivity of the devised method to the changes of face silhouettes shapes, defined above as „non-mathematical" objects.

At least, two fragments of pseudo-information similarity measuring for asymmetric faces are shown in Fig.27. Combined vectors *F* and *L* include five facial components (*Z*=5: mouth, left eye and left brow, right eye and right brow).

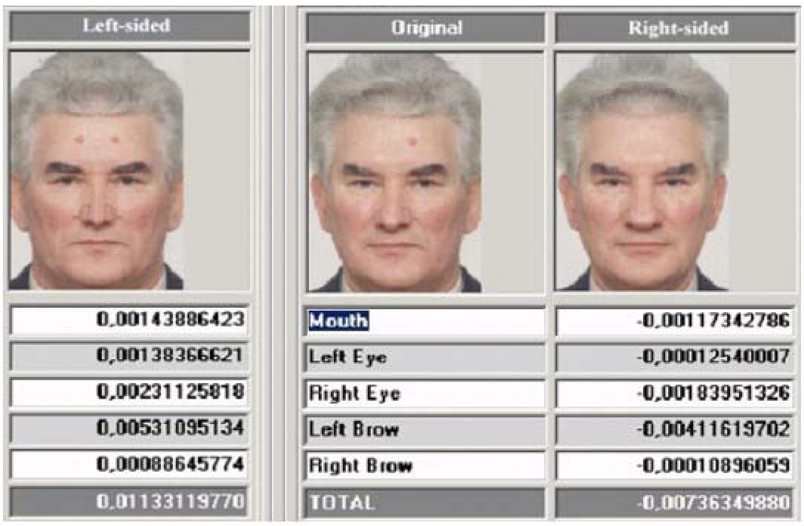


Fig. 27 Results of the pseudo-information similarity of the face pairs evaluation. (The values must be multiplied by 100, see Eq.(2))

In spite of the fact that selected facial component sets are not representative enough for face similarity estimation, the following conclusions may be drawn: a) Pseudo-information similarity values, by means of which the effect of evaluating face asymmetry features for neutral and basic emotional states are compared, are sensitive to the effects. b) The division of similarity vectors on the components gives additional information possibilities to apply teaching procedure; that is a recognition procedure may be robust to facial emotional states, for example by means of usage of weighting learning procedure.

10. Main study results

To work up new research direction called *Biometrics of Asymmetrical Face,* the following theses have been accepted:

T1. Known face models in artificial intelligence, virtual reality, live biometrics are based on the idea of symmetry of both face and head. In traditional applications, it is the cause of geometrical value errors of about 5-7%. Moreover, in the mentioned fields only physiologic and behavioral human being characteristics are used. To gain new results and expand the range of modern research in the field of person's authentication/identification to progressive interdisciplinary requirements there is not only the need for searching new physiological or behavioral biometrics, but also for using their new types, especially some cognition-psyche characteristics (constructs).

T2. The actual direction to work out the thesis may be as follows. There has to be created a face model containing traditional biometric information as well as „subtle" primary face information that already used in psychological constructs identification. With this aim, in our case, Czestochowa-faces would be created. The model treatise is based on modern knowledge about face authentication/identification methods, functional brain hemispheres asymmetry and ophthalmogeometry phenomena, the knowledge of psychological testing of personnel types. Next, the study of algorithmic methods of gaining and interpretation of traditional biometric, as well as psychological (cognitive) information should be presented.

In the paper, the positive result of an initial development of the theses is presented.

R1. The created presentation of facial image called Czestochowa-face, which contains traditional and subtle information on biometrics and/or psychological constructs (person's cognition-psyche characteristics).

R2. The created new biometric (and psychometric) method is based on information concerning person's ophthalmogeometrical pattern.

R3. The created new biometric (and psychometric) method is based on information concerning person's face asymmetry.

R4. Some interesting novelties of joint researching the facial asymmetry and ophthalmogeometry phenomena have been noticed: the uniqueness of the facial asymmetry and ophthalmogeometry characteristics; topologic non-changeability of person's ophthalmogeometric pattern; the possibility of using point 3 of the ophthalmogeometrical pattern as an indicator of the dominant brain hemisphere; the uniqueness and significant prevalence of the face image normalization using the unit called *Muld*; the usage of a image oversampling procedure for saving eyes sketch in the magnification of low pictures; etc

The new face presentation and synthesized algorithms for precise mapping, comparing and interpretation of facial features and psychological states have been devised from the basics for the needs of modern and far-reaching techniques in the fields of live biometrics, artificial intelligence, psychological testing, personality types identification, and so on.

Czestochowa-faces were called in analogy to the existing types of Fisher-, eigen-, wavelet-faces. With respect to the fact that this model regards the modern knowledge about face asymmetry phenomena, brain asymmetry and ophthalmogeometry, as well as having the possibility of precise and scaled asymmetric faces mapping in *Mulds*, this model can be classified as an interdisciplinary facial model of new generation.

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