BIO-TECNOLOGIES IN COMPUTER SCIENCE: THE PROMISES, THE HYPE AND THE REALITY

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Abstract

In this paper we try answer the question how use our knowledge about biological objects in computer science? It is well known many examples of very useful using this knowledge in theory and practice. For example, neural network is one of the models of a brain, genetic algorithms based on principle evolution living objects, fuzzy logic is more real model of making decision when part information is unknown or not correct. Information from biological objects have unique feature which help solve the problem of person's identification and recognition. Many problems we can't solve in modern computer systems, and researches have search the answer in bio-systems. So, bio-computing based on some principles of organization of living objects. In this paper we analyzed achievements in this domain. We present our point of view on the problem of mapping modern Bio - technologies onto some computer science problems. We consider two main directions: (i) identification and recognition of biological objects based on feature extraction from biometric information (voice, thermal images, fingerprints et.al.), and (ii) new calculation technique based on bio-principles (biomolecular computing, and DNA computing. The paper have the discussion character, as invitation for discussion with the main goal better understand the role and the place of modern bio-informatics. <Diana>

Key words: *Bio-informatics, Bio - (information, technologies, computing), Biometric (information, technique, technologies)*<Diana>

1. Introduction

Bio-informatics are the fast developing scientific direction, studying the processes of creation, transmission, reception, storage, processing, displaying and interpretation of information in all the channels of functional and signal systems of living objects which are known to biological and medical science and practice [Pol95]. Modern natural sciences at present sharply need in the updating of scientific picture of the world, and the essential contribution in this process can be made by the biometric and biomedical methods.

Only some more simple (statistical) forms of bio-information have found their application when person identification, and raised interest for these methods of identification can be caused by new possibilities of information technologies. Intensively studying the problem how to use bio-principles for other applications, for example, for computing based on biomolecular [Diana] and DNA [Diana] principles.

Bio - informatics is interdisciplinary direction which used modern achievements in biologic, medicine, genetic engineering, computing science and others. Two main directions of modern Bio - technologies are very attractive for many applied problems: (i) identification of biological objects and (ii) technical realization of some principals of organization of biological objects. We consentrain our attention in these direction only.

First direction used for identification of biological objects special type information, so called *biometric information.* This information (from voice, fingerprint, handwritten, hand geometry and so on) processing by methods of recognition, identification, image analysis and so on. Biometric information can be classified as *contact* and *non-contact* methods. For example, for recognition biological object by voice or identification of a person by eyes it is don't require contacts with biological objects, that is why these methods of recognition and identification are classified as non-contact methods. Clear, that contact methods need direct or mediate contact with biological object. For example, person's identification methods based on fingerprints and signature need paper or special devises for input these objects (special features of these objects) to a computer. Note, that in many papers reported about more exotic methods. So, concept of electromagnetic is intensively investigated at present. New results have been obtained in fractal analysis, using which an attempt was taken to explain some paradoxical phenomena such as morphogenetic field, distant cells communications, anomalously high sensitivity of organism to near-zero frequency perturbations, regulation processes critical dependence on the fractal features of noisy environment, etc. [Pol95].

The main idea of the second direction is using in computer science some principles of organization living objects including there intellect. We can illustrate it on a number of well known in artificial intelligent examples. So, neural networks (NN) is result of study of human brain. Genetic algorithms, is directly inspired by Darwin's theory of evolution. These algorithms constantly *mutate* into new software patterns. Once a better way to solve a problem is found, the improved method becomes the programmer's norm. Then the mutation and selection cycle starts all over again.

Fuzzy logic is the result of studying the problem how the person make the decision in many situation related with non correct and uncertainty information. Now fuzzy logic methods help, for example, automatic cameras decide which part of image should be in focus. It is more really model of thinking process in some cases. Also, some very advanced, *machine-learning* software is being used to recognize patterns in complex data and to analyze problems. It is another model of human thinking.

Very promising approach to design new generation of computer systems based on biomolecular and DNA principles study know very intensively [ ]. Biomolecular computer is a computer based on dynamism of biomolecular activities. High efficiently this computer on parallel distribution logical information represented by varieties of biological molecules [Aoki]. So, the main advantage of biomolecular computing is the massive parallelism. Unfortunately biotechnological infrastructure is not yet mature enough and we can not say about design of biomolecular computers.

It is important understand achievements in these direction of computer science which have the common platform: they are used bio-information and principles of organization of living objects. From this quite general position we can see new approaches to solve problems. But we limited our discussion only two directions of bio-informatics, namely; (i) using biometric information for person's identification, and (ii) using some biometric principles for calculating. It is our goal and motivation of our study and this paper.

From the above mentioned point of view, this paper can be classified as invitation for discussion. We are finding answers for next questions:

- How influence bio-principles and bio-concepts into computer science?
- Which knowledge about living objects are used in computer science, and in industry of informatics ?
- <Diana>

2. Notation

We analyzed many papers, but we didn't found the determination of *bio-informatics.* But we can indicate exactly the main features of this direction : using *biometric information* and *biometric concepts (principals).* It is clear, that information which obtained from biological objects is called *bio-information.* The methods, algorithms and tools for bio-information processing are called *bio-technologies.* Bio-information and bio-technology are quite general concepts and they include *biometric information* and *biometric technologies* (Fig.1). In most papers and in industry these terms used often as equivalence term person's identification and recognition methods and tools. Many types of information used for this, for example, acoustic, visual, electromagnetic information.

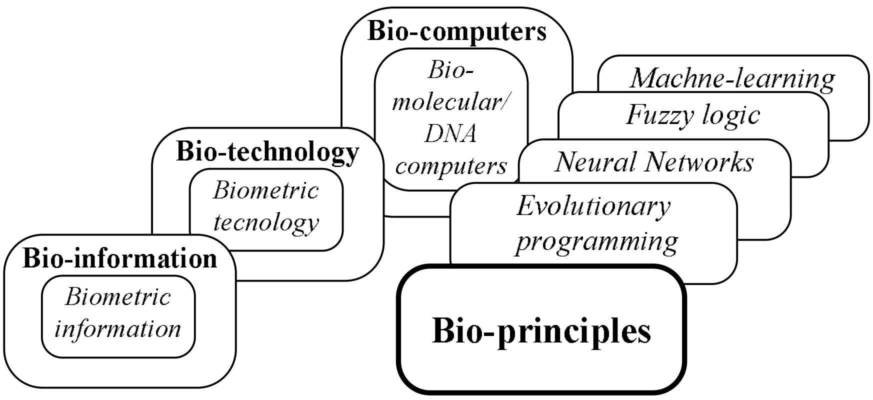

Fig.1. Basics notations of bio-informatics

Terms *bio-computing or bio-computer* mean that computation based on the dynamism of biomolecular activities. Many methods and algorithms of computer science based on different *bio-principles (concepts),* for example, principle of evolutionary is used in genetic algorithms, principles of brain's structure are used NN, principals of biomolecular structure and dynamism of biomolecular activities are used in bio-computers (Fig.1).

Bio-molecular computations <Diana>

DNA based computation<Diana>

3. Classification

It is very useful try to classified bio-information and bio-principles which are used in bio-informatic. This classification is not full, but we can evaluate state of the art in many direction of computer science and industry which are used biometric information or based on biometric principles.

3.1. Extraction of bio- information

Modern methods and devices extract bio-information from biological object

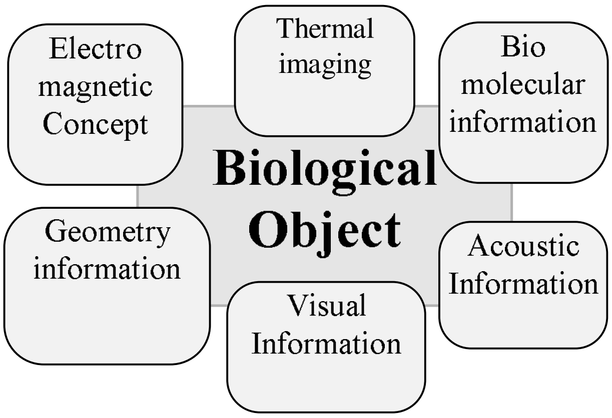

Fig. 2.Biometrical information from biological object which is used in many directions of computer science for practical applications and studying living objects

in many ways. Fig.2 illustrate some of the more useful nowadays: from visual image, voice (acoustic), size and configuration (geometry), thermal image, biomolecular, electromagnetic field. In processing of extraction we can obtain unique feature of a living objects. Now it is used mostly for person's authorization and recognition. But the goal of study some kinds of fields of living objects more general, for example how to control such fields. Answers to this and related questions are open knew possibilities in communication and calculation [pol95]

3.2. Biological Principles

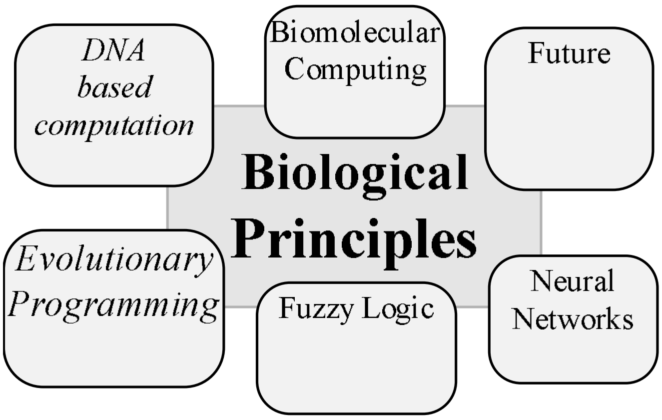

Fig. 3. Principles of living objects are the basics of many approachies in computing science

4. Levels of Understanding and Modeling of Biological Objects in Computer Science

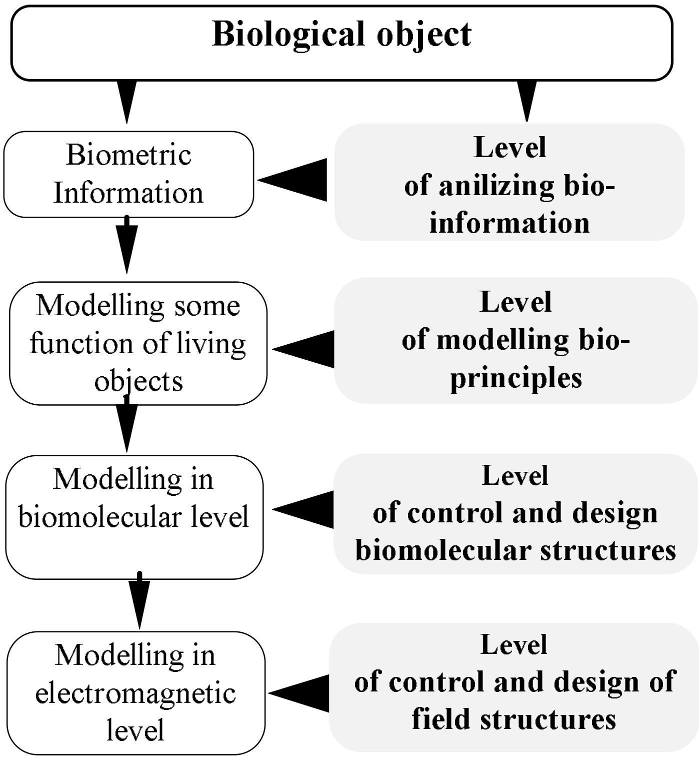

Fig.4. Levels of applications knowledge about biological objects in computer sciens

In Fig.4 we introduced levels of applications of modern understanding and knowledge about biological objects as mapping to problems of computer science.

First level includes methods and tools which solved some problems based on *analyzing* of biometrics information. First of all it is problems of person's authentication and recognition (biometrics technology - BT). We discuss these in sections 5 and 6 of this paper.

Second level, from our point of view, based on using in computation or solving problems biometrics *principals and concepts*. For example, NN is the model of brain's construction, genetic algorithm is the model of evolution, fuzzy logic is the model of making decision when part information is unknown or have fuzzy character.

At the third level researches try to use in computing principles of biomolecular structure. The main feature of this level is that are used *real biomolecular structure* (not models) and the problem is to find methods of building and *control* bio-molecular processing. We discuss this question in section 7 of this paper.

Forth level includes principle new, fantastic opportunity in communication and computing. Now very intensively study many phenomena of living objects connecting with special kinds of fields. In some papers reported results of experiments with such fields which can be consider as a new type of memory, environment of processing and communication. In some cases these fields can be controlled.

Note that developing and improving of practical applications of our knowledge about living objects at the first level based on the achievements of the second level. For example, NN, GA and fuzzy logic are powerful tools in studying and processing of biometric information. In other words it means that for study biological objects are used methods based on bio-principles. This fact have deep philosophical base. In this connection in some papers forecasting that this trend will be have place in next levels of practical applications of knowledge about biological objects (Fig.4, dotted lines).

5. State of the Art Biometric Technologies

Nowadays term BTs means: *voice and speech recognition, dynamic signature and handwriting capture, eyes (iris and retinal) identification, hand geometry, fingerprint (palm print) identification, face recognition and keystroke dynamics* (Fig. 5).

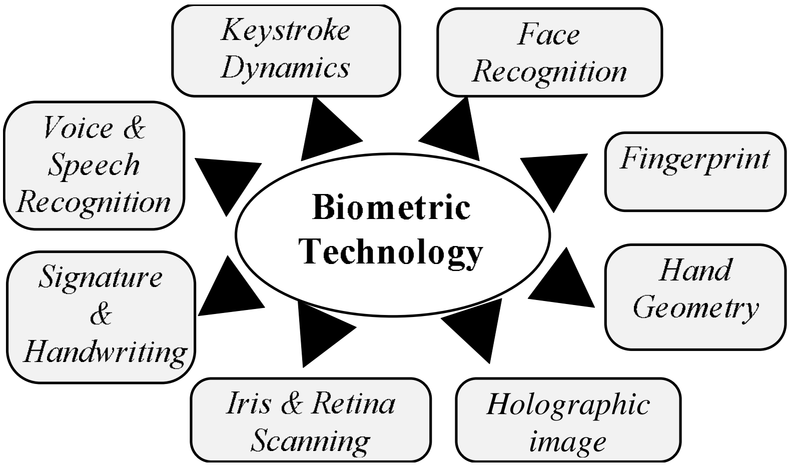

Fig.5. Main directions of modern BTs

In a number of cases, *thermal imaging* of a living objects is also used. Possibly, it should be classified as a separate direction of BTs.

It is quite clear from Fig.5 the modern view of BTs. It is doesn't mean, that BTs includes this direction only. We say about the direction rich are used now in many practical applications. It is well known about many others investigation in biometrics, but these methods can be called as *laboratory's BTs methods and approaches*. We don't discuss their in this paper, but many experts predict development of not-touch methods BTs, i.e. methods which allow identifying the person on distance.

The areas of BTs application is dynamically extend. It is possible to explain partially by that problems of information safety became priority for the present stage of IT development. The hopes on BTs are in many respects justified and their use frequently gives good results.

The modern BTs applications mainly concentrate in the following areas: *medical, law and order, banking and finance, immigration control, visual and voice communications, access control* (Fig.6). No doubt, everybody already met various biometric devices, which called in another way.

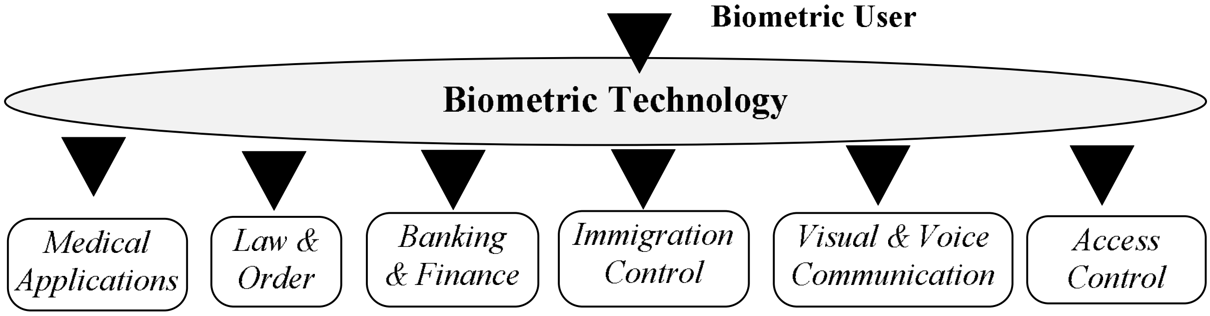

Fig.6. Main modern BT applications

5.1. Fingerprints

The application which most people are familiar with in this area are Automatic Fingerprint Identification Systems (AFIS) as used by police forces across the world (PRINT-PAK-ORION Systems, MORPHO Systems, NEC Systems, COGENT Systems, and others). BTs have in this direction rather deep historical roots (from the mid 1880) and enough experience accumulated in criminology [Chap].

The problem of automation of this activity is solved during last decades, and rather impressive results were achieved. The numerous other applications of the fingerprint authentication products are, as a rule, special cases of AFIS. Therefore it is expediently to consider a place of image processing and pattern recognition methods in such systems.

Most automatic systems for fingerprint comparison are based on *minutiae* matching (local discontinuities in the fingerprint pattern). The American National Standards Institute has proposed a minutiae classification based on four classes*: terminations, bifurcations, trifurcations and undetermined* [Amer].

Many approaches to automatic minutiae extraction have been proposed, for instance, resent papers [Hali], [Maio], [Mech]. However always is realized next technology: *<Input fingerprint image> <Improvement of legibility and smoothing out> <Outlining> <Binarization> <Thinning> <Extraction of minutiae>.*

It is typical for the fingerprint image that the finger is usually not printed uniformly: one part of it is extremely light and other part dark, so methods based on global threshold finding fail. There are also other causes to make necessary the pre-processing of fingerprint image.

Thus, for example, a NN based on self organizing feature maps is proposed for fingerprint classification [Hali]. The author's results show that a NN that is trained with a sufficiently large and representative set of samples can be used as an indexing mechanism for a fingerprint database, so that it does not need to be retrained for each fingerprint added to the database.

NN are often applied to compress fingerprint images. The following technology is used: by learning with self-supervision, NN finds near-optimal clustering from image data and builds a compression codebook in the weight connections.

5.1. Signature and handwriting authentication

Nowadays the automatic investigation of handwritten objects (for example, there are handwritten text, signature, short letter, notes) has been widely used: to confirm the document authenticity in the financial sphere; to solve the expert problems in criminology; to diagnose the physical and psychic state of patients in medicine; to make the psychological individual analysis in psychology and others.

This area of BTs is enough explored by specialists in graphology, psychology and medicine, and modern systems apply often the results obtained by in criminology. However, many revered approaches are differed essentially from the classic ones.

Computer analysis of handwriting signature and handwriting is very interesting research area. Most of the work done in this area has made use of real-time input (i.e., handwriting objects are input to the computer by means of light pen, table, and so on), so that the time sequence of strokes in the signature and handwriting is known. Little has been done on the analysis of these objects that is input to the computer by scanning and digitizing of source documents.

Automatic reading of unknown signature and handwriting is difficult problem. Signature and handwriting varies greatly, even for a single individual. It is hard to segment unknown signature and handwriting words into letters or strokes. This becomes much easier, although it is still quite nontrivial, when the words are known (the case of the signature of known person).

The task of handwriting objects verification is to determine whether a given signature or handwriting is genuine or forgery. In many papers consider the problem of detecting free-hand forgeries, where the forger made no attempt to simulate or trace a genuine signature. In the latter case, the forged handwriting object has the proper shape, but differs from genuine object in the quality of the strokes. Free-hand forgeries, on the other hand, differ from a genuine signature with respect to the values of various size and shape features.

It should be noted, that the ways to solve the problems of authentication signature and handwriting are different. It is connected with the fact that the problem of signature verification is always solved in the conditions of indefinite information. Therefore in graphology frequently take the additional information by other ways, including chemical methods. It is obvious, that there is no such opportunity for commercial (non-professional) applications, and it stimulates researchers for searching new, non-standard decisions.

The problem of handwriting verification requires other approach, as it is possible to gather from the letter, slip or address on the document, as a rule, enough for acceptance of the reliable decision.

It should be noted, that there is the large difference between professional and commercial versions of such the systems.

The design of a signature and handwriting verification system generally requires the solution of next types of problems: *data acquisition, pre-processing, feature extraction, comparison process, and performance evolution*

In a number of causes the design of such systems means the automatization the methods which have good investigated and widely used in police applications. The typical example is considered in [Pena]. A dynamic signature verification system which analyzes signatures dynamically by considering their shape, time, domain characteristics, such as speed and acceleration, and force domain characteristics, i.e. applied pressure, is presented there. Experimental results demonstrate 92% authentic signature detection accuracy and 100% forgery signature detection accuracy.

The following below technology is investigated in many papers. A signature is obtained as a sequence of *x,y*-coordinates of pen-tip movement and writing pressure. The features of a signature are derived from the coordinates and the writing pressure and are decomposed into two principal features, shape and motion.

In [Lee] were proposed on-line dynamic signature verification system with a database of more than 10 000 signatures. Authors extracted a 42-parameter feature set at first, and advanced to set of 49 normalized features that tolerate inconsistencies in genuine signatures while retaining the power to discriminate against forgeries.

In [Huan] for signature verification NN was proposed. Experiments have showed that average 90% test samples can be correctly classified on a data set of over 3000 signature images.

The main point of the approaches supported in [Huan] is the following. Geometric features of input signature image are simultaneously examine under several scales by a NN classifier. An overall match rating is generated by combining the outputs at each scale. Artificially generated genuine and forgery samples from enrollment reference signatures are used to train the NN, which allow definite training control and at the same time significantly reduce the number of enrollment samples required to achieve good performance.

The methods of fuzzy logic and evolutionary programming are also often used to solve the problem [Xuhu], [Zhou]. There are known the papers which reported about very good results of off-line signature verification system based on fuzzy logic.

An example of realization of once more original idea is the results represented in [Cui]. The hand movement is tightly coupled with spatial recognition (hand shape). The system uses the multiclass, multidimensional discriminate analysis to automatically select the most discriminating features for gesture classification. Authors propose a recursive partition approximate to do classification. The framework has been tested to recognize 28 different signatures. The experimental results show that the system can achieve a 93,1% recognition rate for test sequences that have not been used in the training phase.

Two different approaches have been taken to capture the signature dynamics: an active pen and sensitive tablet. For example, a document can be sent by the Email, authorized by a signature which do not have graphic form. This signature includes parameters of pressure, the number of times the pen was lifted from the paper and so on. It is an easy means of security.

To be noted, the information stored in such way is insufficient to match criminological expertise, which required from 6 to 20 original objects (depending on signature complexity).

Some approaches to work out professional signature and handwriting identification systems were reported in [ShmY], [ShmK], [Abla]. Such systems are characterized by that they meet the requirements accepted for criminology.

It also should be pay an attention for papers [Amma], [Plam] and [Lee], where very optimistic results were achieved.

As example of high efficient practical devices we can speak about so called SMARTpen (LSI Computer Group N.V., USA). SMARTpen is a ball-pen that includes sensors allowing authentication of a person through the biometric characteristics of their signature. This device is very user friendly and based on the modern technique of signature authentication. So, the pen tip's trajectory, as calculated, will a 3D curve lying around the plane (the writing surface). The curve is projected on that plane representing the pen tip's path along the paper, this path is the written text, incorporating unique characteristics of the writer. Therefore signature verification with this device does not depend on graphic image of the signature but on the dynamics of the act of signing. The dynamics are strictly personal and thus allow the authentication of the signer [biom].

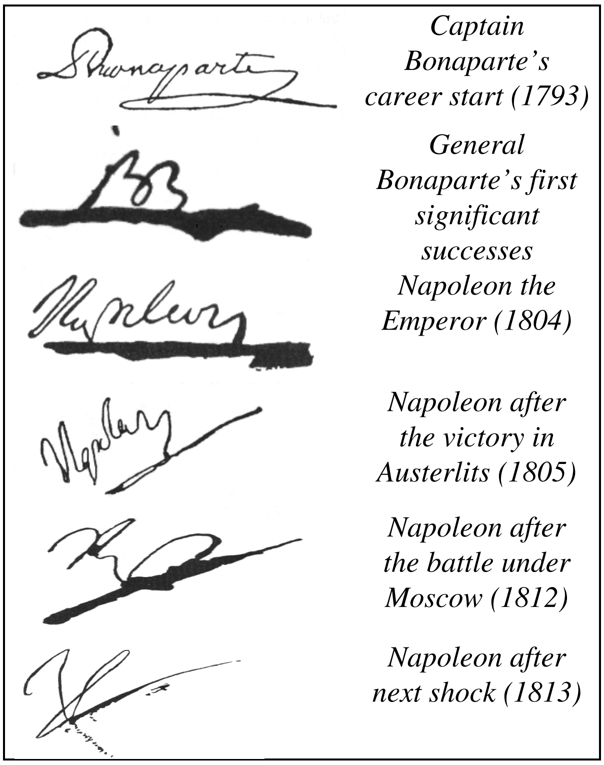

Fig.7. Change of the signature of Napoleon after some historical events on an during 20 years

The experts-graphologists have accumulated rather large experience in handwriting and signature authentication, what now begins to be used in various commercial applications. We pay our attention only for one factor of the given BTs direction, namely the timing instability of the given form of biometric information. It is well-known, that handwriting and signature of a person strongly correlates with his mood and feeling. As one of paradoxical examples, we consider a few Napoleon the Emperor's signatures made at the most significant shocks in

his (and Europe!) life (Fig.7) [Morg]. On the other hand, this signatures illustrate not only graphical features, so, their processing allow obtaining the quite significant characteristic such as signature dynamics.

It was stressed in the beginning of this section that commercial systems use often the experience of policy. However, the classic approaches are also mainly not automated. At the best it is possible to speak about automation some stages of signature and handwriting verification. In it easily to be convinced when visiting the appropriate division of police.

5.3. Eyes identification

Traditionally use two ways to identify the eyes. These ways differ in accordance with the zones of eye, from which the attributes are obtained: (i) the blood vessels on the retina, and (ii) iris. These systems are most secure biometrics and require to apply rather complex methods of image processing (further we demonstrate elements of this technology). The iris identification systems looks promising for the future, as allows to use standard means (telechamber and processor), whereas retina systems require special and expensive devices (retina scanning devices).

Many papers are concentrated on radial basis function feed-forward NN. Their authors affirm that such NN are more assimilated for the given type of objects.

One of problems is an iris localization for a head-mounted eye tracker. The tracker must gaze direction to be measured by supplying simultaneous views of a subjects eye and of the world from a head-mounted camera. Finding gaze direction relative to the head requires accurate and robust measurement of the iris outline under a wide range of lighting conditions, in the presence of highlights, and when the iris is in an extreme position.

Some approaches for eyes identification are referred more in detail in [Absa] and [Herp]. In [Sol97] we reported our results too.

5.4. Face Identification

Facial recognition is also a convenient means of identification. Researchers in computer vision and pattern recognition have worked on automatic techniques for recognizing human faces for the last 20 years. In facial recognition system computers perform three classical tasks: *verification* (the system attempts to match a life face with a specific reference digital image), *recognition* (the system try to match a live face with any saved faces in a central computer database), and *locating* the face within the image.

One of the problems is face recognition under varying pose. Sometimes use the next technology: (i) representation of faces with templates from multiple model views that cover different poses from the viewing sphere, (ii) recognition of a novel view, the recognizer locates the eyes and nose features, uses these locations to geometrically register the input model views, (iii) using the correlation on model templates to find the best match in the database of base of people.

One of the very important steps of this process is determination the best facial features to discriminate the features of one face from those of another.

Human face detection is another interest problem considered in many papers. An edge-enhancing preprocessor and some separately trained backpropagation NN are often applied for this problem. Many authors report about good results on using the NN at the first stage of face recognition: determines general properties of the input, such as whether the facial image contains glasses or a beard.

This direction attracts the serious attention of specialists last years. It is connected with that many problems have not been solved yet in this direction. The technology of face image recognition can be explained with the illustration on Fig.8. The idea consists in search of conformity (on determined criteria) face model to face image. This idea is realized with staircase procedures of processing (from above downwards to face image and from below upwards to face model). The set of the factors influences for search of an optimum way, which comes to an end by identification or recognition. The major factors are specified on Fig.8: expression, illumination and so on.

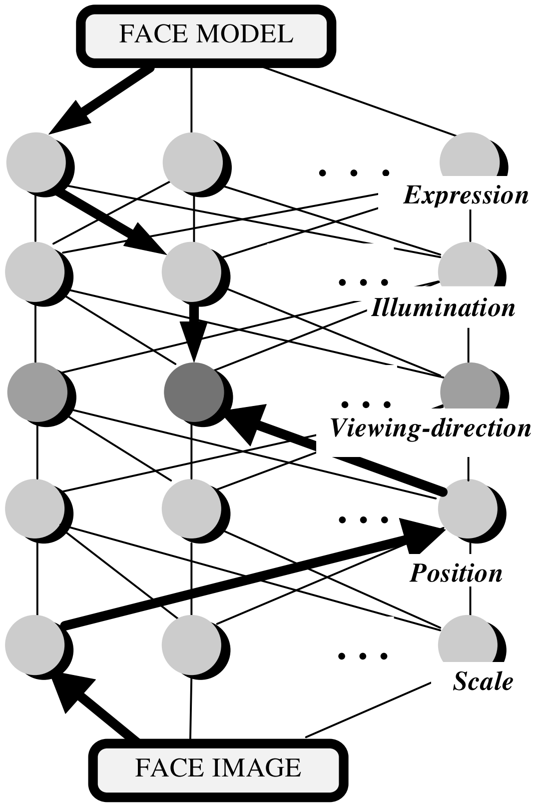

Fig.8. Technology of face image recognition

So, in [Ezza] the image - based model is build using example views of the face, by passing the need for any three-dimensional computer graphics models. A learning NN is trained to associate each of the example images with a set of pose and expression parameters. In [Folt] a wavelet decomposition technique or morphological non-linear filtering is used to enhance intrinsic features of a face, reduce the influence of rotation in depth, changes in facial expression, glasses and lighting conditions. In [Yoko] the method to detect human face regions precisely, without imposing any constraints on the face size, position or features (glasses, beard, and so on), employs a genetic algorithm. The proposed method detects the edges in input image, and it searches elliptical regions.

It is necessary to emphasize, that using the tomography methods allow solving many problems of face recognition. However these methods requires large computational cost.

It is the not complete list of original ideas in this area. Visual communication is another application of the BT. Now this direction has been extensively studied, especially in the psychology literature.

It should be noted that face recognition - one of few investigated directions BTs. The commercial applications of such systems are known, however they work at a number rather strong restrictions.

4. Methods of BTs

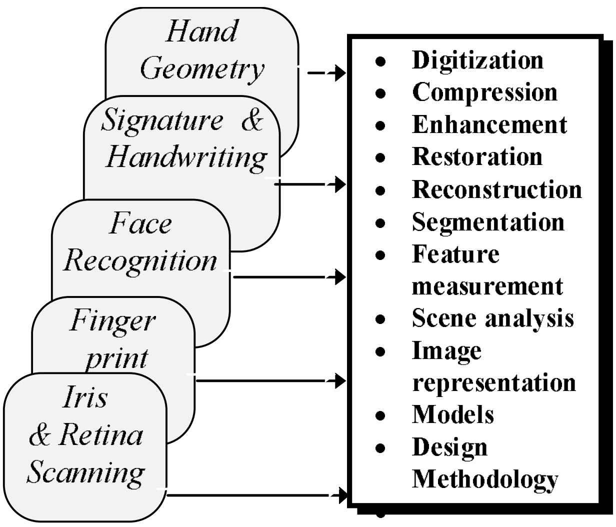

Fig. 9. Implementation of some BTs requires to use practically all modern achievements in image processing and pattern recognition

The analysis shows, that the overwhelming part of BTs is realized by using image processing and pattern recognition methods and algorithms (Fig.9).

Note, that the distance BTs require to use additionally the tomography methods, however it is not the subject of the present paper.

Typically, a number samples are taken at time (speech, signature) and processed in accordance with a chosen method. An intermediate image is formed as result.

It is interesting to compare storage requirements for these templates for various BTs (Fig.10).

The number varies between nine bytes to more than one thousand. It is feasible to store the large numbers of templates in standard memory media.

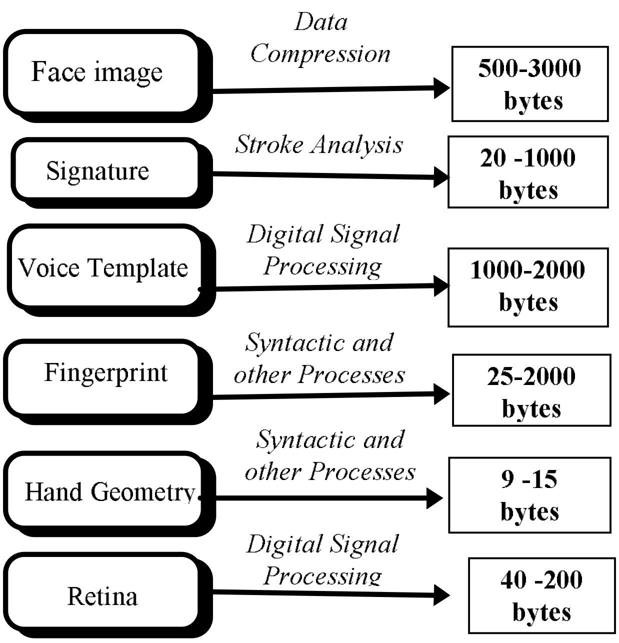

Fig.10. Space requirements for various biometric data storage

It should be said some words on compression methods for biometric information. For instance, instead of storing an actual image of the fingerprint as the template, most verification devices store a code which relates to the location of the minutiae points on the fingerprint. The template cannot be used to recreate an image of the fingerprint so it is of no use to law enforcement agencies. the templates range in size from 25 to 2000 bytes so can be stored as a bar code, on a magnetic stripe card, smart card or on a central database connected to the owner by a PIN.

To identify a person based on retina scanning technology, it is enough to process 200-300 pixels of the image and then to compress the results by traditional way. From 40 to 200 bytes are enough to store one image.

5. Open Problems in BTs

As any other rather new area of human activity, BTs have not today a system approach to design systems to realize BTs technology. For example, techniques and criterion of a choice of particular BTs for the purposes of applications have not been developed. It stimulates interest of many experts to the given subject area. National Computer Security Association, USA, will perform various biometric projects on behalf of its corporate members as well as Commercial Biometric Developers Consortium members. For the same time, large experience of designing AFIS has been accumulated. The most simple engineering solutions of AFIS are widely used in banking, financial and access control.

BTs application is connected with the decision of many new problems, in particular, legal & social problems, alerts to ethical use, privacy considerations, industry standards, biometric & internet security and others (Fig.14).

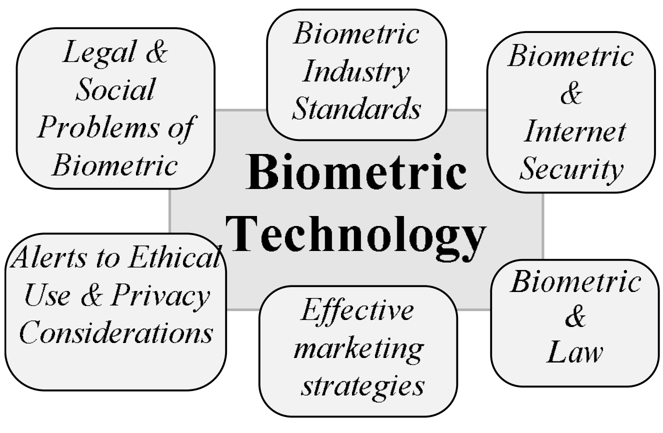

Fig. 11. The future of BTs is connected with solution of many not only engineering problems

On estimations of the experts many problems require non-traditional approaches. However frequently the life much accelerates the decision ethical and social problems, connected to wide by use BTs-systems, for example, national safety, terrorism, immigrations' problem, large losses of financial institutions and etc.

6. Bio-computing
6.1. Biomolecular Devices
6.2. Calculation
6.3. The promises and reality

7. The promises and reality

The modern practical applications BTs make *a small part of our knowledge* about living objects. The distance methods of identification of the person are used at the moment in the elementary variants and presently are the subject for laboratory researches. Today is real such the forms of BTs as fingerprint, as voice and speech, signature and handwriting, eyes, hand geometry, face, keystroke dynamics and others . It means, that rather effectively it is possible to automate processes of identification of the person under these forms of the biometric information and to satisfy with the requirements of many practical applications.

Biometric products design requires knowledge of the modern achievement from many directions of human activity. The realization of any system BTs for commercial application requires *interdisciplinary researches*.

The overwhelming part BTs is closely connected to methods image processing and pattern recognition. It means that many experts of this area can use their knowledge and methods in BTs. BTs is one of areas, for which systems approaches to designing and creation BTs-systems are not developed. The main obstacles are absence of the standards, not enough experience of the existing BTs-systems (excepting fingerprints devices and systems). The effective use BTs requires to solve many social questions, connected to the law, etiquette and others.

Use of methods BTs in educational process gives many interesting effects, main of which is, that stimulates inquisitiveness of the students in study of methods image processing and pattern recognition. It is possible to expect increase of interest to BTs. This forecast is based that BTs effectively supplement traditional ways of identification of the person and in a number of cases it appear more preferable or effective <Diana>

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