

RESEARCH AND DEVELOPMENT
OF LIE DETECTOR BASED ON VIBRAIMAGE TECHNOLOGY

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Introduction

The problem of lie detection has the same long history as the history of mankind development. A possibility of reliable lie detection has always been of interest with people. It is natural that for many years a considerable experience has been gained, various investigations have been carried out, a huge number of lie detection data have been obtained and processed.

Given a minimal time allocated for this work, we have tried to maximally use the already known information and gained in allied areas having reviewed them at a new angle of application and with the account of possibilities, which the *VibraImage* technology provides.

A system being developed in the course of this work will inevitably need subsequent elaboration and improvement, as it has passed minimal practical tests; however even these minimal tests have shown significant prospects of this system.

This report includes sections describing some well-known technologies being used for lie detection or theories connected with determination of the emotional state of man, which have been used at the development of the method and the system being proposed. The information about well-known approaches and generally accepted concepts has been provided in maximum brief, as there is a considerable number of publication on the given topic.

1. *Conventional lie detection methods*

There are a large number of lie detection definitions. Two of them are given below, which demonstrate differences in the understanding of this term by the authors due to a verbatim principle.

A lie is an action, by which one person misleads another person, doing it deliberately, without a prior notice of its own intentions and without a clearly expressed request not to disclose the truth on the part of the victim [1].

A lie is a communication phenomenon consisting of a deliberate distortion of the real state of affairs; most frequently it is expressed in the content of voice messages, which immediate verification is difficult or impossible. It is a conscientious product of verbal activity aiming at misleading the recipients [2].

A lie detector examination is a complicated multicomponent procedure based on a phenomenon of close relationship between emotional, spiritual feelings of man and functioning or vital activity of its physiological systems. This relationship was empirically discovered already in the time of great antiquity and has widely been used at the conduction of various kinds of legal proceedings (examples: African voodoo; a criminal fears unmasking, i.e. he/she feels a fear – a psychic state, which causes the appearance of a specific body odour being a result of activity of certain sweat and other glands; Chinese rice; old Roman physicians – betrayal).

And really, in principle any person can, by various external features, for example, reddening or turning pale, gesticulation, manner of speech, etc., determine what emotional state his/her interlocutor is (quiet/excited, feared/angry, joyful/sad, etc.), especially if the latter do not try to control such a state. However, in most cases, it can be very difficult to determine the state of man by external features; the more so if this state arises and is passing in a very short period of time, e.g. several seconds. It occurs because of most of us can sufficiently easy control our behaviour, i.e. smile when we are scared or stressed, follow our speech, mimicry and gestures and thus seem externally quiet. However if, apart from observation of external features, one tries, by means of a lie detector, to monitor some concealed physiological reactions incapable to volitional control (they include the so-called vegetative reactions, i.e. reactions reflecting the work of internal organs of our life support), then one can clearly watch how accurately, differentially and practically instantly they reflect even insignificant changes in the emotional state of the face being examined [3].

Conventionally, polygraphs (lie detectors – LD) are widely used in the USA, see www.polygraph.org.

In this Web site belonging to the American Polygraph Association, one can get sufficient data on conventional methods and equipment on lie detection.

The main characteristics of conventional LD are as follows:

1. Long time of contact testing (few hours).
2. Lack of automatic mode (expert examination).
3. Relatively low probability of error for good experienced experts (approximately 5%).

Literature:

1. Paul Ekman, *Telling Lies*. W.W. Norton&Company, New York-London.
2. Golovin S.U., *Psycholog-practice dictionary*. ACT, 2001
3. Korovin V.V., *Psychophysiological base of polygraph*. "4 international conference of polygraph application". Sochi, RF, 2000.

2. Modern lie detection methods. Electroencephalographic method

A conventional polygraph was developed in the USA in the 1930s. Approximately at the same time, the first EEG was obtained [1] and an EEG-method for the brain activity investigation was developed. For the last decade, many mathematical methods for EEG analysis have got an increased informativity due to a rapid development of visualisation technologies.

The greatest success and fame in the EEG use for lie detection have been achieved by Dr. Larry Farwell (www.brainwavescience.com) in studying the EEG reaction to an informational influence in a certain period of time (300 ms), the so-called P300 technology [2-22]. The results of investigations have been patented in the USA: US 5406956, US 5467777, US 5363858, and are widely used in practice.

The functionality of Brain Fingerprinting technology insignificantly differs from conventional lie detection methods and allows to reduce the error probability (somewhat more) due to increasing the informational sensitivity. The name of Brain Fingerprinting technology itself underlines the relation to brain functioning processes asserting that any event being engraved in the brain leaves such an indelible trace (there) as a fingerprint.

Literature:

1. Wasserman E.L., Kartashev N.K., Polonnikov R.I., Fractal dynamics of brain electrical activity. St. Petersburg, Nauka. 2004.
2. Farwell, L. A., Chambers, R. D., Miller, G. A., Coles, M. G. H., and Donchin, E. (1985). A Specific Memory Deficit in Elderly Subjects Who Lack A P300. *Psychophysiology*, 23, 589 (Abstract.)
3. Donchin, E., Miller, G. A., and Farwell, L. A. (1986) The Endogenous Components of the Event-Related Potential - A Diagnostic Tool? In *Advances in Brain Research*, 1986. Amsterdam: Elsevier. See also *Progress in Brain Research*, Vol. 70, 1986.
4. Farwell, L. A. and Donchin, E. (1986) The "Brain Detector:" P300 in the Detection of Deception. *Psychophysiology*, 24: 434 (Abstract).
5. Farwell, L. A., Donchin, E., and Kramer, A. F.(1986) Talking Heads: A Mental Prosthesis for Communicating with Event-Related Brain Potentials of the EEG. *Psychophysiology*, 24: 434 (Abstract).
6. Bashore, T.R., Miller, G. A., Farwell, L. A., and Donchin, E. (1987). *Research in Geriatric Psychophysiology*. In *Annual Review of Gerontology and Geriatrics*. New York: Springer.
7. Farwell, L. A. and Donchin, E. (1988) Talking Off The Top Of Your Head: A Mental Prosthesis Utilizing Event-Related Brain Potentials. *Electroencephalography and Clinical Neurophysiology*, 70: 510-513.
8. Farwell, L. A. and Donchin, E. (1988) The Truth Will Out: Interrogative Polygraphy with Event-Related Brain Potentials. *Psychophysiology*, 25:445 (Abstract).
9. Farwell, L. A. and Donchin, E. (1989) Detection of Guilty Knowledge with ERPs. *Psychophysiology*, 26:58. (Abstract of an address presented at the Twenty-Eighth Annual Meeting of the Society for Psychophysiological Research, October, 1989.)
10. Farwell, L. A. and Donchin, E. (1991) The Truth Will Out: Interrogative Polygraphy ("Lie Detection") With Event-Related Brain Potentials. *Psychophysiology*, 28:531-547.
11. Farwell, L. A. (1992) The Brain-wave Information Detection (BID) System: A New Paradigm for Psychophysiological Detection of Information. Doctoral Dissertation, University of Illinois at Urbana-Champaign, 1992.

12. Farwell, L. A. (1992) The Farwell System for Event-Related Brain Potential Information Detection: A New Paradigm in Psychophysiological Detection of Concealed Information. Technical Report prepared for the Office of Research and Development of the Central Intelligence Agency, 1992.
13. Farwell, L. A. (1992) Two New Twists on the Truth Detector: Brain-wave Detection of Occupational Information. *Psychophysiology*, 29,4A:S3 (Abstract of an address presented at the Thirty-Second Annual Meeting at the Society for Psychophysiological Research, October 1992).
14. Farwell, L. A., Martinerie, J. M., Bashore, T. R., and Rapp, P. E. (1993) Optimal Digital Filters for Long Latency Event-Related Brain Potentials. *Psychophysiology*, 30, 3, 306-315.
15. Rapp, P. E., Albano, A.M., Schmah, T.I., and Farwell, L. A. (1993) Filtered Noise Can Mimic Low Dimensional Chaotic Attractors. *Physical Review E*, 47,4, 2289-2297.
16. Farwell, L. A. and Richardson, D. A. (1993) Detection of FBI Agents with the Farwell MERA System: A New Paradigm for Psychophysiological Detection of Concealed Information. Technical Report, Human Brain Research Laboratory, Inc.
17. Farwell, L. A. (1993) Brain MERMERS: Detection of FBI Agents and Crime-Relevant Information with the Farwell MERA System. Proceedings of the International Security Systems Symposium, Washington, D.C.
18. Farwell, L. A. and Farwell, G.W. (1995) Quantum-Mechanical Processes and Consciousness. *Bulletin of the American Physical Society*, 40, 2, 956-57.
19. Farwell, L. A. and Smith, S. S. (2001). Using Brain MERMER Testing to Detect Concealed Knowledge Despite Efforts to Conceal *Journal of Forensic Sciences* 46,1:1-9
20. [U.S. Patent #5,363,858](#): Method and Apparatus for Multifaceted Electroencephalographic Response Analysis (MERA)
21. [U.S. Patent #5,406,956](#): Method and Apparatus for Truth Detection
22. [U.S. Patent #5,467,777](#): Method for Electroencephalographic Information Detection

3. Modern lie detection methods. Voice technologies

The connection between a lie and a voice is evident, and, at the first glance, a man needs to say something in order to tell a lie or a truth. In doing so, the connection between a lie and a verbal brain activity is deeper and will be considered later.

The human voice mechanism is much more complicated than it seems at the first glance. Many small muscles shall work concurrently in a certain sequence in order to pronounce meaningful sounds being transformable into words. In doing so, the brain is narrowly watching everything that is being pronounced and is permanently creating and regulating everything we say. The air from lungs, having passed through vocal chords, generates basic voice elements and then lips, teeth and tongue generate the rest of the words being pronounced. All processes passing in the brain, are reflected during the conversation in a continuous speech flow. It seems that the speech process does not depend upon the environment, but one only needs to somewhat influence on the speaker, for example, pinch him, as the intonation of his speech will immediately change.

The most well-known autonomous voice lie detector is a Truster product (www.911.co.kr), which has an undoubted advantage as compared with a conventional polygraph and other contact technologies of lie detection. The voice technology is contactless and allows analysing the man's state even when he does not guess it. It is well-known that man changes his emotional state when he knows that he is being watched. Consequently, if he wants to conceal his emotions, then he will try to do it. A man who is entangled with cables gets worried even if he has not committed anything blamable, and it also impedes the research. Contactless systems are advantageous, and in this case a probationer knows that he is under control, as some time after the beginning of testing, being in a free environment, man is easier to adapt to the situation and the probability of true reactions will significantly grow.

The voice technologies can instantly show when a man tells a truth and when he tells a lie; in doing so, the analysis can be carried out both by a separate device and by a personal computer (<http://www.nemesysco.com/>) [1], however the probability of the first and second kind errors are sufficiently high. Perhaps, it is connected with the complexity of the tuning process, a high voice changeability and the necessity of monitoring several non-correlated parameters of the man's functional state for an adequate reaction determination.

Literature:

1. Amir Liberman. Voice Analysis – The Truth about the "Truth Machine".

4. Modern lie detection methods. Facial technology

One of the most well-known contemporary psychologists Dr. Paul Ekman has devoted about 50 years of his scientific activity to studying the reflection of psychophysiological and emotional state of man by facial expression (www.paulekman.com) and at the present time is the best specialist in the deception psychology area.

Research works [1-8] contain analysis of the relationship between facial expression and emotions based on their own data and the results of other investigations; in doing so, the problem complexity and the ambiguousness of simple judgments are underlined. Ekman states that people that have passed education and training according to this method begin catching a lie much better; at that Ekman pays a special attention to expression asymmetry.

Conventionally, one can consider the Ekman's theory to be a non-automated version of the VibraImage technology; however an expert and visual facial control essentially restricts the possibility of observation of insignificant manifestations of the autonomous nervous system reactions.

Literature:

1. Ekman P. Telling lies: clues to deceit in the marketplace, marriage, and politics. Third edition with two new chapters, W.W. Norton, 2002.
2. Ekman P. Emotions revealed. New York: Times Books (US). London: Weidenfeld & Nicolson (world).
3. Ekman P. (Editor) Charles Darwin's. The expression of the emotions in man and animals. Third Edition, with Introduction, Afterwords and Commentaries by Paul Ekman. London: HarperCollins, New York: Oxford University Press. New York: Times Books (US). London: Weidenfeld & Nicolson (world). 1998.
4. Ekman P. & Friesen W. V. Unmasking the face: a guide to recognizing emotions from facial clues. New Jersey: Prentice Hall, 1975. Reprint edition, 2003, Cambridge, Ma: Malor Books. A guide to how emotion is registered in each part of the face. Over 100 photographs.
5. Ekman P., Campos J., Davidson R.J., De Waals F. Emotions inside out. Volume 1000. New York: Annals of the New York Academy of Sciences 2003.
6. Ekman P., Friesen W.V., & Hager J.C. The facial action coding system. Second edition. Salt Lake City: Research Nexus eBook. London: Weidenfeld & Nicolson (world). 2002.
7. Ekman P., & Rosenberg E.L. (1997). What the face reveals: basic and applied studies of spontaneous expression using the facial action coding system (facs). New York: Oxford University Press. Second expanded edition 2004.
8. Ekman P. & Davidson R. The nature of emotion: fundamental questions. New York: Oxford University Press. 1997.

5. VibraImage technology as a detector of man's psychophysiological and emotional state

VibraImage (VI) technology allows visualising the movement of both separate points on the human body in respect of each other and parts of the man's body in space by means of a normal television camera and a special software (www.elsys.ru).

At the present time various tests are under way concerning the interconnection between VI parameters and the man's psychophysiological state (PCT WO 02/51154).

A VI type being obtained can considerably be changed depending upon various settings and filtration similarly to obtaining a normal image of the object, which can significantly change in the visible, IR and UV wavebands, or depending upon the exposure time. VI parameter change under fixed settings gives evidence of a change of the man's functional state similarly to such conventional parameters being measured by a lie detector as respiration rate, pulse rate, change of the blood pressure or electric resistance of skin.

The fact that all organism functions, with no exceptions, are peculiar to a low-frequency fluctuation dynamics has been well-known long ago. Several fundamental theories have been developed not being directly connected with the matter in question (LD) but directly concerning the general characteristics of processes passing in a human organism and, consequently, being also directly connected with any partial function of the man's vital functions, including a lie function.

It is assumed that the interrelation between VI and the man's psychophysiological state is proved by the following generally known scientific theories:

1. Theory of self-organised criticality
2. Theory of fractal dynamics
3. Functional brain asymmetry.

Literature:

1. VibraImage technology – opportunity of contactless analyse of psychophysiological human conditions. Elsys Corp., St. Petersburg, RF, 2004.
2. PCT WO 02/51154 Method, device and system for gathering information.

6. Self-organised criticality

A universal flicker-noise theory proposed in 1987 by P. Bak et al and having been developed during subsequent years is called a theory of self-organised criticality [1-4]. A success of this theory is mostly connected with the fact that its authors have set themselves the task of finding an explanation of a nature of fluctuations with a $1/f$ (b) type spectrum in any complicated interactive systems, which are taken to mean non-equilibrium systems consisting of a large number of mutually interacting non-linear elements.

It is evident that all objects being studied by biology and, first of all, human's belong to this class.

Literature:

1. Bak P., Tang C., Wiesenfeld K., Self-organized criticality: an explanation of $1/f$ noise. Phys. Rev. Lett., 1987. Vol. 59, N4, p.381-384.
2. Dickman R., Muñoz M. A., Vespignani A, Zapper S., Paths to self-organized criticality. 2001.
3. Donald L. Turcotte. Self-organized criticality. Rep. Prog. Phys. 62 (1999) 1377-1429.
4. Telemedicine. New information technology on a threshold of XXI century. Editors by Prof. R.M. Yusupov and Prof. R.I. Polonnikov. St. Petersburg, 1998.

7. Analysis of fractal dynamics

For the last 20 years, scientists from the whole world have more and more frequently been using new geometrical concepts. One of such concepts that have changed the conventional ideas in geometry has become a fractal concept. It was introduced in 1975 by a French mathematician B. Mandelbrot [1]. The main property of fractals is self-similarity. If a randomness algorithm is activated at the fractal creation, then random fractals, or multifractals, arise. Professor R. I. Polonnikov [2, 3, 4] (St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences, Russian Federation) uses the analysis of fractal dynamics (AFD) for the operational EEG analysis based on his assumptions on the structure of the brain electric activity process [4]. This structure combines three main components, namely: regular fractals, fractal fluctuations and biorhythms. The second important AFD idea is the preference of informational characteristics of analysis rather than its energy characteristics. The third idea of the method concerns spatial-temporal and spatial-frequency characteristics of analysis.

The principles set forth above have something being closely in common with the *VI* analysis; though *VI* analysis uses mechanical rather than electric properties of the object.

Literature:

1. Mandelbrot B.B., Van Ness J.W. Fractional Brownian motions, fractional noises and applications. SIAM Review. 1968. Vol. 10, N 4, p.422-437.
2. Telemedicine. New information technology on a threshold of XXI century. Editors by Prof. R.M. Yusupov and Prof. R.I. Polonnikov. St. Petersburg, 1998.
3. Polonnikov R.I. Quasi – metaphysical problems. St. Petersburg, Anatolia, 2003.
4. Wasserman E.L., Kartashev N.K., Polonnikov R.I., Fractal dynamics of brain electrical activity. St. Petersburg, Nauka. 2004.

8. Functional asymmetry of the brain

The lie function investigation by means of the results obtained by studying the functional asymmetry (of brain) can be of interest if one can manage to prove that one of the hemispheres is responsible for this function. Multiyear research conducted in the Laboratory of functional asymmetry of the brain in the I. M. Sechenov Institute of Evolutional Physiology and Biochemistry of the Russian Academy of Sciences, St. Petersburg, Russian Federation [1], assume that the left hemisphere plays the leading role in the generation of a lie whereas it is the right hemisphere that delivers a lie.

The left hemisphere specialises in processing discrete elements, in particular, recognition and generation of phonemes (symbolic signs), information categorisation, grammar decoration of statements; the right hemisphere processes iconic signs based on a continuum property, for example, it specialises in perception and generation of a whole musical image, intonation, (mimicry), picture, in identification and memorisation of faces, emotional expressions, recognition of subject noises, distinguishing between male and female voices. So the left hemisphere provides verbal communication and the right hemisphere provides non-verbal forms of communication.

The interaction between hemispheres occurs: a) by a complementarity type, when both brain hemispheres complement each other in the process of performance of a certain function; b) by a superposition type, when both hemispheres, in the course of performance of a function, permit distortions being opposite by sign, which get neutralised as a result of interaction between hemispheres.

In the speech and thought activity, the complementarity type manifests itself in the fact that each hemisphere generates its own principles of speech organisation: 1. right hemisphere generates the wholeness of notional content, provides empirical or picturesque metaphoric thinking, creates association based on vivid and sensible ideas of a subject; the left hemisphere provides theoretical thinking, grammar decoration of a statement and characteristics of the subject properties; 2. the generation of a man's lexicon structure occurs due to the summation of various vocabulary layers: the right hemisphere is supported by a picturesque imaging of the object world whereas the left hemisphere rests on the concept-words.

At the spatial depth perception under the brain hemisphere interaction, the superposition manifests itself in the fact that distorting projections of three-dimensional space get neutralised when the right hemisphere underestimates distances (i.e. overestimates the near space) whereas the left hemisphere overestimates distances (i.e. overestimates the far space).

The right hemisphere carries out a direct subjective count of the current time whereas the left hemisphere performs an abstract count of the objective time by its symbolic designation on a clock (having no dial-face divisions or figures) and by a conventional calendar pattern.

The right hemisphere structures are connected with mechanisms of picturesque memory, including topographic memory, and the left hemisphere structures are connected with mechanisms of verbal memory.

The right hemisphere activity predominance is connected with a shift towards negative emotions and the left hemisphere tone rise is connected with a shift towards positive emotions.

In the normal state, the left hemisphere tone prevails providing a high level of vigil and the consciousness control.

The verbal and logic left hemisphere is the carrier of a leaned knowledge, a formal solution of logic problems. An assumption arises that the left hemisphere also possesses the knowledge of how to deceive those being around by telling them a lie. However the left hemisphere possesses an alness, a sluggishness of thinking and is, in this sense, vulnerable.

1) By proposing a solution for syllogisms (they can be solved only by a formal and logic method), one can introduce false premises relying on the fact that the left hemisphere will take them on trust, without verification of the truthfulness/falseness of premises. For example:

1. All precious metals do not rust.
2. Molybdenum is a precious metal.
Does molybdenum rust or not?

When solving syllogisms with false premises, a probationer will be thrown into a dilemma, namely: whether to answer according to the formal logic (and thus sinning against the truth) or follow the life experience (empirical thinking in the “right hemisphere manner”) entering into a cognitive dissonance with the formal logic being intrinsic for him.

2) Propose 32 statements to the probationers, replies to which can be interpreted as a high probability of a probationer’s insincerity (a lie). For example: “I do quickly forget if somebody offends me”.

This questionnaire has been elaborated on the basis of a modification of several psychological scales (including a “Lie” scale) according to the following works [2-6].

3) As the left hemisphere impedes non-verbal communication, then a necessity arises to estimate its peculiarities, i.e. an ability to maintain a visual contact; the frequency and expressiveness of gestures by the right hand and the left hand; a degree of symmetry/asymmetry of facial movements during a smile. So according to Ekman (1984), facial movements are distinguished by a symmetry during a true (experienced) smile and by an asymmetry during a deliberate smile.

Literature:

1. Deglin V.L. Lectures about functional asymmetry of human brain. Geneva Initiative on Psychology, Amsterdam-Kiev, 1996.
2. Sobchik L.N. Standardised multifactor method for studying a personality – MMPI; St. Petersburg, Rech Publishing House, 2001.
3. Kellerman-Plutchik’s questionnaire – “Protective mechanisms”, Internet.
4. Detection of accentuations. Adapted characterological questionnaire by K. Leongard – G. Shmishek. Practical training on age psychology, a collection edited by L.A. Golovey, E.F. Rybalko, St. Petersburg, Rech Publishing House, 2001.
5. Assessment of demand in approval, a procedure by D. Crown and D. Marlow, adapted by Yu.L. Khanin. Practical training on age psychology, a collection edited by L.A. Golovey, E.F. Rybalko, St. Petersburg, Rech Publishing House, 2001.
6. A personality scale of manifest anxiety (J. Taylor), modified by V.G. Norakidze. Practical training on age psychology, a collection edited by L.A. Golovey, E.F. Rybalko, St. Petersburg, Rech Publishing House, 2001.

Conclusion

In the course of development and investigation of a possibility of creation of a lie detector based on the VibraImage technology, the following works have been executed:

1. A patent and informational analysis of various lie detection technologies has been carried out.
2. A new lie detection technology has been developed on the basis of the VI technology.
3. Various lie detection procedures have been elaborated and tested.
4. A functioning lie detection system based on the VI technology has been developed.
5. The software developed allows to register, in a contactless manner, the change of man's psychophysiological parameters in the automatic and manual modes.
6. The change of man's psychophysiological state has been tested and the lie detection has been carried out by means of the systems and procedures being developed.
7. A brief scientific and technical report on this work has been drawn up.

The results obtained have shown a possibility of using the VibraLie system for lie detection at the level of similar conventional and modern lie detectors.

In doing so, the VibraLie system uses the best qualities of various lie detection technologies:

1. A possibility of registration of insignificant changes of the man's psychophysiological state (a conventional polygraph).
2. A high sensitivity to the brain activity (electroencephalographic methods).
3. Comfort and lack of contacts in respect of the testing object in combination with an instantaneous analysis (voice technologies).
4. A possibility of a non-verbal lie analysis (facial technologies).

The results obtained are of significant practical and scientific value, have all novelty and unobviousness criteria and can be patented.

A flexible structure of the system software will allow to easily make requisite addenda and use new parameters for registration of the man's state after conduction of tests for the whole system in the full volume and in various conditions.

It seems feasible to use this system not only for lie detection but also for various psychophysiological tests.