INTERPRETATION OF THE EMOTION CHARACTERISTICS THROUGH THE ANALYSIS OF ATTRACTORS RECONSTRUCTED ON EEG SIGNALS

Filatova Natalia Nikolaevna
Professor at Technological Processes Automation department,
Tver State Technical University
Russia, 170026, Tver, 22 Afanasy Nikitin Emb., TSTU. E-mail: nfilatova99@mail.ru

Sidorov Konstantin Vladimirovich
Associate Professor at Technological Processes Automation department,
Tver State Technical University
Russia, 170026, Tver, 22 Afanasy Nikitin Emb., TSTU. E-mail: bmisidorov@mail.ru

Received 19.06.2016, revised 24.06.2016.

The article describes a dynamic model that allows to monitor a change in the direction of human emotions development in the course of a sequence reactions to external stimuli. This problem is solved by forming a new system of signs characterizing the morphology of the attractor reconstructed from the EEG signals. Changes in the testee emotional state are evaluated using a fuzzy estimation of the three characteristics of the attractors reconstructed EEG signals. The emotions monitoring results are presented in the form of a matrix with increments of the attractors characteristics assessments, defined by the additional index scale that allows for each element of a fuzzy set to generate a numerical evaluation using the index term and the membership function.

Keywords: model of emotion, emotion recognition, attractor, fuzzy sets.

Nechetkie Sistemy i Myagkie Vychisleniya [Fuzzy Systems and Soft Computing], 2016, vol. 11, no. 1, pp. 57–76.

References

[1] Lebedeva N.N., Karimova E.D. The acoustic characteristics of the speech signal as an indicator of the human functional state. *Uspekhi Fiziologicheskikh Nauk* [Advances in Physiological Sciences], 2014, vol. 45(1), pp. 57-95. (in Russian)

[2] Koelstra S. Affective and implicit tagging using facial expressions and electroencephalography: PhD Thesis. London: Queen Mary University of London, 2012. 167 p.

[3] Rozaliev V.L., Bobkov A.S., Orlova Yu.A., Zaboleeva-Zotova A.V., Dmitriev A.S. Detailed analysis of postures and gestures for the identification of human emotional reactions. *World Applied Sciences Journal*, 2013, vol. 24, spec. issue 24: Information Technologies in Modern Industry, Education & Society, pp. 151-158. doi: 10.5829/idosi.wasj.2013.24.itmies.80028

[4] Rangayyan R.M. *Biomedical Signal Analysis*: 2nd Edition. New York, United States: Wiley-IEEE Press, 2015. 720 p. doi: 10.1002/9781119068129

[5] Malineckij G.G., Potapov A.B. *Sovremennye Problemy Nelinejnoj Dinamiki* [Modern Problems of Nonlinear Dynamics]. Editorial URSS Publ., Moscow, 2000. 336 p. (in Russian)

[6] Anishhenko V.S. *Znakomstvo s Nelinejnoj Dinamikoj: ucheb. posobie* [Introduction to Nonlinear Dynamics Handbook]. LKI Publ., Moscow, 2008. 224 p. (in Russian)

[7] Starchenko I.B., Pererenko J.S., Borisova O.S., Momot T.V. Nonlinear dynamics methods for biomedical applications. *Izvestiya SFedU. Engineering Sciences*, 2010, vol. 110, no. 9, pp. 42-51. (in Russian)

[8] Abhang P.A., Gawali B.W. Correlation of EEG images and speech signals for emotion analysis. *British Journal of Applied Science & Technology*, 2015, vol. 10(5), pp. 1–13. doi: 10.9734/BJAST/2015/19000

[9] Lokannavar S., Lahane P., Gangurde A., Chidre P. Emotion recognition using EEG signals. *International Journal of Advanced Research in Computer and Communication Engineering*, 2015, vol. 4(5), pp. 54–56. doi: 10.17148/IJARCCE.2015.4512

[10] Lan Z., Sourina O., Wang L., Liu Y. Real-time EEG-based emotion monitoring using stable features. *The Visual Computer*, 2016, vol. 32(3), pp. 347-358. doi: 10.1007/s00371-015-1183-y

[11] Sidorov K.V., Filatova N.N.. Biotechnical system for the analysis of human emotions. *Trudy Kongressa po intellektualnym sistemam i informatsionnym tekhnologiyam «IS&IT'14»* [Proceedings of the Congress on Intelligent Systems and Information Technologies «IS&IT'14»]. Moscow, Fizmatlit Publ., 2014, vol. 2, pp. 238-244. (in Russian)

[12] Takens F. Detecting strange attractors in turbulence. *Dynamical Systems and Turbulence: Proceedings of a Symposium Held at the University of Warwick 1979/80*. Ed. by D. Rand and L.-S. Young. Berlin, Germany: Springer Berlin Heidelberg, 1981. Vol. 898, in Lecture Notes in Mathematics. Pp. 366–381. doi: 10.1007/BFb0091924

[13] Fraser A.M. Reconstructing attractors from scalar time series: A comparison of singular system and redundancy criteria. *Physica D: Nonlinear Phenomena*, 1989, vol. 34(3), pp. 391–404. doi: 10.1016/0167-2789(89)90263-7

[14] Fraiser A.M., Swinney H.L. Independent coordinates for strange attractors from mutual information. *Physical Review A*, 1986, vol. 33(2), pp. 1134–1140. doi: 10.1103/PhysRevA.33.1134

[15] Gorshkov V.A., Kasatkin S.A. *Identifikacija Vremennyh Ryadov Aviacionnyh Sobytij Metodami i Algoritmami Nelinejnoj Dinamiki* [Identification of Time Series of Aviation Events by Methods and Algorithms for Nonlinear Dynamics]. Blank Design Publ., Moscow, 2008. 208 p. (in Russian)

[16] Grassberger P., Procaccia I. Measuring the strangeness of strange attractors. *Physica D: Nonlinear Phenomena*, 1983, vol. 9(1-2), pp. 189–208. doi: 10.1016/0167-2789(83)90298-1

[17] Eckmann J.-P., Ruelle D. Ergodic theory of chaos and strange attractors. *Reviews of Modern Physics*, 1985, vol. 57(3), pp. 617–656. doi: 10.1103/RevModPhys.57.617

[18] Mekler A.A. *The Software Package for the Analysis of Electroencephalograms using Dynamic Chaos Theory*. PhD Thesis. Saint-Petersburg, 2006. 168 p. (in Russian)

[19] Theiler J. Spurious dimension from correlation algorithms applied to limited time series data. *Physical Review A*, 1986, vol. 34(3), pp. 2427–2432. doi: 10.1103/PhysRevA.34.2427

[20] Perervenko Ju.S. *Investigation of Invariants of Non-Linear Dynamics of Speech and the Principles of Construction of the Audio Analysis System of Psychophysiological State*. PhD Thesis. Taganrog, 2009. 175 p. (in Russian)

[21] Borisova O.S. *Research and Analysis of Electroencephalographic Data by Native Methods of Nonlinear Dynamics*. PhD Thesis. Taganrog, 2010. 163 p. (in Russian)

[22] Lebedeva N.N., Karimova E.D., Kazimirova E.A. Speech signal analysis in human functional state research. *Biomediczinskaya radioe'lektronika* [Biomedical Radioelectronics], 2015, no. 2, pp. 3–12. (in Russian)

[23] Sidorov K.V., Filatova N.N. Application of nonlinear dynamics methods for joy emotion recognition in speech. *Nauchno-tehnicheskii vestnik informatsionnykh tekhnologii, mekhaniki i optiki* [Scientific and Technical Journal of Information Technologies, Mechanics and Optics], 2012, vol. 12(5), pp. 110–114. (in Russian)

[24] Filatova N.N., Sidorov K.V., Terekhin S.A. Software package for interpretation of nonverbal information by analyzing speech patterns or electroencephalogram. *Programmnye produkty i sistemy* [Software & Systems], 2015, vol. 111(3), pp. 22-27. (in Russian). doi:10.15827/0236-235X.111.022-027

[25] Filatova N.N., Sidorov K.V., Iliasov L.V. Automated system for analyzing and interpreting nonverbal information. *International Journal of Applied Engineering Research*, 2015, vol. 10(24), pp. 45741–45749.

[26] Filatova N.N., Sidorov K.V., Terekhin S.A., Vinogradov G.P. The system for the study of the dynamics of human emotional response using fuzzy trends. *Proceedings of the First International Scientific Conference «Intelligent Information Technologies for Industry» (IITI'16)*, vol. 451. In Advances in Intelligent Systems and Computing / Ed. by A. Abraham, S. Kovalev, V. Tarassov, V. Snasel. Cham, Switzerland: Springer International Publishing, 2016. Vol. 2, Part III. Pp. 175–184. doi: 10.1007/978-3-319-33816-3_18

[27] Lapshina T.N. *Psychophysiological Diagnosis of Human Emotions based on EEG Indices*. PhD Thesis. Moscow, 2007. 190 p. (in Russian)

[28] Milovidov A.A., Filatova N.N. The program complex for linguistic interpretation of graphic dependencies with fuzzy coordinates of central points. *Programmnye produkty i sistemy* [Software & Systems], 2011, vol. 95(3), pp. 110–114. (in Russian)

[29] Filatova N.N., Milovidov A.A. Analysis and interpretation of audiograms in the space of fuzzy attributes. *Nechetkie Sistemy i Myagkie Vychisleniya* [Fuzzy Systems and Soft Computing], 2011, vol. 6(1), pp. 55–66. (in Russian)

Bibliographic citation

Filatova N.N., Sidorov K.V. Interpretation of the emotion characteristics through the analysis of attractors reconstructed on EEG signals. *Nechetkie Sistemy i Myagkie Vychisleniya* [Fuzzy Systems and Soft Computing], 2016, vol. 11, no. 1, pp. 57–76. (in Russian)