Povzetek

Signali opisujejo potek spreminjanja poljubne fizikalne količine, s katero merimo nek proces. So tok informacij. Analiza signalov je široko področje, ki ima temelje v matematiki, uporablja pa se v fiziki, elektrotehniki, strojništvu, medicini in biologiji. Cilj analize signalov je izluščiti čim več informacij iz signalov, da bi tako bolje razumeli dogodke in pojave, ki jih proučujemo.

V prvem poglavju se bomo posvetili Fourierovi transformaciji, ki je osnovno matematično orodje za analizo signalov. Izpeljali bomo dva klasična rezultata, to sta Heisenbergovo načelo nedoločenosti, ki postavi meje natančnosti časovno-frekvenčne analize, in Shannonov izrek o vzorčenju, ki pove, kako moramo analogne signale zajemati, da jih lahko brez izgube informacij spremenimo v digitalne.

V drugem poglavju bomo spoznali več časovno-frekvenčnih porazdelitev in analizirali njihove prednosti in slabosti. Večino teh predstavitev bomo izpeljali iz Wigner-Villove porazdelitve.

V tretjem, zadnjem, poglavju bomo z metodami, ki smo jih spoznali, analizirali gravitacijske valove, ki jih je septembra 2015 zaznal observatorij Ligo.

Math. Subj. Class. (2010): 94A12, 42C40, 44A15

Ključne besede: analiza signalov, Fourierova transformacija, konvolucija, Heisenbergovo načelo nedoločenosti, časovno-frekvenčna analiza, valčki, Wigner-Villova porazdelitev, Cohenov razred, gravitacijski valovi

Keywords: signal analysis, Fourier transform, convolution, Heisenberg's uncertainty principle, time-frequency analysis, wavelets, Wigner-Ville distribution, Cohen's class, gravitational waves

Literatura

[1] B. P. Abbott *et al.*, *Observation of Gravitational Waves from a Binary Black Hole Merger*, Physical Review Letters 116 (2016), 061102-1–061102-16.

[2] R. L. Allen, D. Mills, *Signal Analysis: Time, Frequency, Scale, and Structure*, Wiley-IEEE Press, Piscataway, 2004.

[3] F. Auger, P. Flandrin, P. Gonçalvès, O. Lemoine, *Time-Frequency toolbox for use with MATLAB, Tutorial*, CNRS (France) and Rice University (USA), 1996, (spletni vir, obiskano 18. 4. 2016). Dostopno na `http://tftb.nongnu.org/tutorial.pdf`

[4] I. Al Balushi, *Schwartz Class*, (spletni vir, obiskano 11. 4. 2016). Dostopno na `http://www.math.mcgill.ca/gantumur/math581w12/downloads/Lecture12.pdf`

[5] C. P. L. Berry *et al.*, *Parameter estimation for binary neutron-star coalescences with realistic noise during the Advanced LIGO era*, Astrophysical Journal 804(2):114(24), 2015, (spletni vir, obiskano 12. 5. 2016). Dostopno na `https://arxiv.org/abs/1411.6934`

[6] B. Boashash (editor), *Time Frequency Signal Analysis and Processing, A Comprehensive Reference*, Elsevier, Oxford, 2003.

[7] J. B. Camp, N. J. Cornish, *Gravitational Wave Astronomy*, Annual Review of Nuclear and Particle Science 54 (2004), 525–577.

[8] L. Cohen, *Time-frequency distributions–a review*, Proceedings of the IEEE, 77, 7 (1989), 941–981

[9] M. X. Cohen, *Analyzing Neural Time Series Data: Theory and Practice*, MIT Press, Cambridge, 2014.

[10] M. X. Cohen, *Fundamentals of Time-Frequency Analyses in Matlab/Octave*, sinc(x) Press, 2014.

[11] M. Dörfler, *Gabor Analysis for a Class of Signals called Music*, University of Vienna, 2002, (spletni vir, obiskano 18. 4. 2016). Dostopno na `https://www.univie.ac.at/nuhag-php/bibtex/open_files/do02_diss.pdf`

[12] L. Debnath (editor), *Wavelet Transforms and Time-Frequency Signal Analysis*, Springer Science+Business Media, New York, 2001.

[13] P. S. R. Diniz, E. A. B. da Silva, S. L. Netto, *Digital Signal Processing: System Analysis and Design, Second Edition*, Cambridge University Press, Cambridge, 2010.

[14] P. Flandrin, *On Separability, Positivity and Minimum Uncertainty in Time-Frequency Energy Distributions*, IEEE Trans. Signal Proc 40, (1998), 1746–1757.

[15] T. Giannakopoulos, A. Pikrakis, *Introduction to Audio Analysis: A MATLAB Approach*, Elsevier, Oxford, 2014.

[16] G. Gopalan, *An Introduction to Signal and System Analysis*, Nelson Education, Scarborough, 2009.

[17] K. Gröchenig, *Foundations of Time-Frequency Analysis*, Springer Science+Business Media, New York, 2001.

[18] K. Gröchenig, Y. Lyubarskii, K. Seip (editors), *Operator-Related Function Theory and Time-Frequency Analysis, The Abel Symposium 2012*, Springer International Publishing, Cham, 2015.

[19] M. Hannam, S. Husa, J. A. González, U. Sperhake, B. Brügmann, *Where post-Newtonian and numerical-relativity waveforms meet*, Phys. Rev. D 77, 4 (2008), 044020–044035.

[20] J. A. Hogan, J. D. Lakey, *Time-Frequency and Time-Scale Methods: Adaptive Decompositions, Uncertainty Principles, and Sampling*, Birkhäuser, Boston, 2005.

[21] P. Honeiné, C. Richard, P. Flandrin, *Time-frequency learning machines*, IEEE Transactions on Signal Processing 55, 7 (2007), 3930–3936.

[22] R. L. Hudson, *When is the Wigner quasi-probability density non-negative?*, Reports on Mathematical Physics 6, 2 (1974), 249–252.

[23] Y.-W. Liu, *Hilbert Transform and Applications, Fourier Transform Applications, Dr Salih Salih (Ed.)*, InTech, Rijeka, 2012 (spletni vir, obiskano 3. 5. 2016). Dostopno na `http://www.intechopen.com/books/fourier-transform-applications/hilbert-transform-and-applications`.

[24] S. Mallat, *A Wavelet Tour of Signal Processing, Second Edition*, Academic Press, San Diego, 1999.

[25] A. Mertins, *Signal Analysis: Wavelets, Filter Banks, Time-Frequency Transforms and Applications*, John Wiley & Sons, Chichester, 1999.

[26] A. Papandreou-Suppappola, *Applications in Time-Frequency Signal Processing*, CRC Press, Boca Raton, 2002.

[27] A. D. Poularikas (editor), *Transforms and Applications Handbook, Third Edition*, CRC Press, Boca Raton, 2010.

[28] L. Praxmeyer, J. Mostowski, K. Wódkiewicz, *Hydrogen atom in phase space: The Wigner representation*, 2008, (spletni vir, obiskano 3. 5. 2016). Dostopno na `http://arxiv.org/pdf/quant-ph/0504038v1.pdf`

[29] R. San José Estépar, *Local Structure Tensor for Multidimensional Signal Processing. Applications to Medical Image Analysis.*, Presses universitaires de Louvain, Louvain-la-Neuve, 2007.

[30] E. Sejdić, I. Djurović, J. Jiang, *Time-frequency feature representation using energy concentration: An overview of recent advances.*, Digit. Signal Process. 19, 1 (2009), 153–183.

[31] L. Stanković, *Digital Signal Processing: with selected topics: Adaptive Systems, Time-Frequency Analysis, Sparse Signal Processing*, CreateSpace Independent Publishing Platform, North Charleston, 2015.

[32] S. Tomažič, *Digitalne komunikacije*, Ljubljana, 2012, (spletni vir, obiskano 3. 5. 2016). Dostopno na `http://www.lait.fe.uni-lj.si/gradiva/DK/DK_ST.pdf`

[33] C. Valens, *A Really Friendly Guide to Wavelets*, 1999, (spletni vir, obiskano 3. 5. 2016). Dostopno na `http://www.polyvalens.com/`

[34] J. Žibert, *Časovno-frekvenčne predstavitve govornih signalov*, magistrsko delo, Univerza v Ljubljani, Fakulteta za elektrotehniko, Ljubljana, 2001.