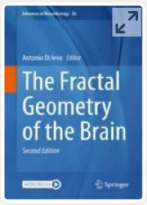

The Fractal Geometry of the Brain pp 487–499

Multifractal Analysis of Brain Tumor Interface in Glioblastoma

Jacksson Sánchez & Miguel Martín-Landrove

Chapter | First Online: 12 October 2023

Part of the book series: Advances in Neurobiology
((NEUROBIOL,volume 36))

Abstract

The dynamics of tumor growth is a very complex process, generally accompanied by numerous chromosomal aberrations that determine its genetic and dynamical heterogeneity. Consequently, the tumor interface exhibits a non-regular and heterogeneous behavior often described by a single fractal dimension. A more suitable approach is to consider the tumor interface as a multifractal object that can be described by a set of generalized fractal dimensions. In the present work, detrended fluctuation and multifractal analysis are used to characterize the complexity of glioblastoma.

Keywords

Multifractal **Glioblastoma** **Fractal dynamics**

Complexity

References

1. Lopes R, Dubois P, Bhouri I, Bedoui MH, Maouche S, Betrouni N. Local fractal and multifractal features for volumic texture characterization. Pattern Recognit. 2011;44:1690–7

2. Oudjemia S, Girault J-M, Derguini N, Haddab S. Multifractal analysis: application to medical imaging. In: 2013 8th international workshop on systems, signal processing and their applications (WoSSPA). 2013. p. 244–9

3. Jelinek HF, Milošević NT, Karperien A, Krstonošić B. Box-counting and multifractal analysis in neuronal and glial classification. In: Dumitrache L, (editors) Advances in intelligent control systems and computer science. Advances in intelligent systems and computing, vol 187. Berlin: Springer; 2013. p. 177–89

4. Reza SMS, Mays R, Iftekharuddin KM. Multifractal detrended fluctuation analysis shows promise for brain tumor grading. In: Proceedings of imaging systems and applications 2014, IW4C; 2014

5. Reza SMS, Mays R, Iftekharuddin KM. Multi-fractal detrended texture feature for brain tumor classification. In: Proceedings of the SPIE 9414, medical imaging 2015: computer-aided diagnosis; 2015. p. 941410

6. Reza SMS, Samad MD, Shboul ZA, Jones KA, Iftekharuddin KM. Glioma grading using structural magnetic resonance imaging and molecular data. J Med Imaging. 2019;6:024501

7. Wang J, Shao W, Kim J. Automated classification for brain MRIs based on 2D MF-DFA method. Fractals. 2020;28:2050109

8. Islam A, Reza SMS, Iftekharuddin KM. Multifractal texture estimation for detection and segmentation of brain tumors. IEEE Trans Biomed Eng. 2013;60:3204–3215

9. Reza S, Iftekharuddin KM. Multi-class abnormal brain tissue segmentation using texture features. In: Proceedings NCI MICCAI-BRATS; 2013. p. 38–42

10. Reza S, Iftekharuddin KM. Multi-fractal texture features for brain tumor and edema segmentation. In: Proceedings volume 9035, medical imaging 2014: computer-aided diagnosis; 2014. p. 903503

11. Reza SMS, Islam A, Iftekharuddin KM. Texture estimation for abnormal tissue segmentation in brain MRI. In: Di Ieva A. (editors) The fractal geometry of the brain. Springer series in computational neuroscience; 2016. p. 333–49

12. Lahmiri S. Glioma detection based on multi-fractal features of segmented brain MRI by particle swarm optimization techniques. Biomed Signal Process Control. 2017;31:148–55

13. Islam A, Iftekharuddin KM, Ogg RJ, Laningham FH, Sivakumar B. Multifractal modeling, segmentation, prediction, and statistical validation of posterior fossa tumors. In: Proceedings volume 6915, medical imaging 2008: computer-aided diagnosis; 2008. p. 69153C

14. Khider M, Haddad B. Local multifractal analysis by 2D-WTMM method to detect brain tumor. In: 2013 UKSim 15th international conference on computer modelling and simulation; 2013. p. 461–4

15. Reza SMS, Samad MD, Shboul ZA, Jones KA, Iftekharuddin KM. Glioma grading using structural magnetic resonance imaging and molecular data. J Med Imaging. 2019;6:024501

16. Gilanie1 G, Bajwa UI, Waraich MM, Anwar MW, Ullah H. An automated and risk free WHO grading of glioma from MRI images using CNN, Multimedia tools and applications; 2022. https://doi.org/10.1007/s11042-022-13415-9

17. Farzana W, Shboul ZA, Temtam A, Iftekharuddin KM. Uncertainty estimation in classification of mgnt using radiogenomics for glioblastoma patients. In: K. Drukker, K.M. Iftekharuddin, H. Lu, M.A. Mazurowski, C. Muramatsu, R.K. Samala, editors. Proceedings of SPIE, medical imaging 2022: computer-aided diagnosis 120331E (1–7). Bellingham: Society of Photo-Optical Instrumentation Engineers; 2022

18. Abd-Ellaha MK, Awadb AI, Khalafd AAM, Hamedd HFA. A review on brain tumor diagnosis from MRI images: practical implications, key achievements, and lessons learned. Magn Reson Imaging. 2019;61:300–318

19. Pei L, Bakas S, Vossough A, Reza SMS, Davatzikos C,

Iftekharuddin KM. Longitudinal brain tumor segmentation prediction in MRI using feature and label fusion. Biomed Signal Process Control. 2020;55:101648

20. Sadique MS, Temtam A, Lappinen E, Iftekharuddin KM. Radiomic texture feature descriptor to distinguish recurrent brain tumor from radiation necrosis using multimodal MRI. In: Proceedings SPIE 12033, medical imaging 2022: computer-aided diagnosis; 2022. p. 120332I

21. Zook JM, Iftekharuddin KM. Statistical analysis of fractal-based brain tumor detection algorithms. Magn Reson Imaging. 2005;23:671–8

22. Di Ieva A, Göd S, Grabner G, Grizzi F, Sherif C, Matula C, Tschabitscher M, Trattnig S. Three-dimensional susceptibility-weighted imaging at 7 T using fractal-based quantitative analysis to grade gliomas. Neuroradiology 2013;55:35–40

23. Di Ieva A, Grizzi F, Sherif C, Matula C, Tschabitscher M, Angioarchitectural heterogeneity in human glioblastoma multiforme: a fractal-based histopathological assessment. Microvasc Res 2011;81:222–230

24. Di Ieva A, Bruner E, Widhalm G, Minchev G, Tschabitscher M, Grizzi F. Computer-assisted and fractal-based morphometric assessment of microvascularity in histological specimens of gliomas. Sci Rep 2012;2:429

25. Lenka S, Kumar S, Mishra S, Jena KK. An IoT-cloud based fractal model for brain tumor image analysis. In: Proceedings of the fourth international conference on I-SMAC (IoT in social, mobile, analytics and cloud) (I-SMAC); 2020. p. 1–7

26. Brú A, Pastor JM, Fernaud I, Brú I, Melle S, Berenguer C. Super-rough dynamics on tumor growth. Phys Rev Lett. 1998;81:4008–11

27. Brú A, Albertos S, Subiza JL, López García-Asenjo J, Brú. The universal dynamics of tumor growth. Biophys J. 2003;85:2948–2961

28. Brú A, Casero D, de Franciscis A, Herrero MA. Fractal analysis and tumour growth. Math Comput Modell. 2008;47:546–559

29. Brú, Alós E, Nuño JC, Fernández de Dios M. Scaling in complex systems: a link between the dynamics of networks and growing interfaces. Sci Rep. 2014;4:7550

30. Martín-Landrove M, Pereira D. Fractal properties and critical exponents in tumor. Ciencia. 2008;16:203–7

31. Torres Hoyos F, Martín-Landrove M. 3-D in vivo brain tumor geometry study by scaling analysis. Phys A Stat Mech Its Appl 2012;391:1195–206

32. Martín-Landrove M, Brú A, Rueda-Toicen A, Torres-Hoyos F. Tumor growth in the brain: complexity and fractality. In: Di Ieva A, editors. The fractal geometry of the brain. Springer series in computational neuroscience. New York; Springer; 2016

33. Martín-Landrove M, Torres-Hoyos F, Rueda-Toicen A. Complexity of brain tumors. Phys A: Stat Mech Its Appl 2020;537:122696

34. Chang H, Fontenay GV, Han J, Cong G, Baehner FL, Gray W, Spellman PT, Parvin B. Morphometic analysis of TCGA

glioblastoma multiforme. BMC Bioinfor 2011;12:484

35. Clark K, Vendt B, Smith K, Freymann J, Kirby J, Koppel P, Moore S, Phillips S, Maffitt D, Pringle M, Tarbox L, Prior F. The cancer imaging archive (TCIA): maintaining and operating a public information repository. Digit Imaging 2013;26:1045–57

36. Scarpace L, Mikkelsen T, Cha S, Rao S, Tekchandani S, Gutman D, Saltz JH, Erickson BJ, Pedano N, Flanders AE, Barnholtz-Sloan J, Ostrom Q, Barboriak D, Pierce LJ. Radiology data from the cancer genome atlas glioblastoma multiforme [TCGA-GBM] collection [Data set]. The cancer imaging archive. 2016. https://doi.org/10.7937/K9/TCIA.2016.RNYFUYE9

37. Baid U, Ghodasara S, Mohan S,Bilello M, Calabrese E, Colak E, Farahani K, Kalpathy-Cramer J, Kitamura FC. The RSNA-ASNR-MICCAI BraTS 2021 benchmark on brain tumor segmentation and radiogenomic classification. arXiv:2107.02314v2 [cs.CV]. 2021. https://doi.org/10.48550/arXiv.2107.02314

38. Menze BH, Jakab A, Bauer S, Kalpathy-Cramer J, Farahani K, Kirby J, Burren Y, Porz N, Slotboom J. The multimodal brain tumor image segmentation benchmark (BRATS). IEEE Trans Med Imaging. 2014;34:1993–2024

39. Bakas S, Akbari H, Sotiras A, Bilello M, Rozycki M, Kirby JS, Freymann JB, Farahani K, Davatzikos C. Advancing the cancer genome atlas glioma MRI collections with expert segmentation labels and radiomic features. Sci Data. 2017;4:170117

40. Weller M, Stupp R, Reifenberger G, Brandes AA, van den Bent MJ, Wick W, Hegi ME. MGMT promoter methylation

in malignant gliomas: ready for personalized medicine? Nat Rev Neurol. 2010;6:39–51

41. Yu W, Zhang L, Wei1 Q, Shao A. O6-methylguanine-DNA methyltransferase (MGMT): challenges and new opportunities in glioma chemotherapy. Front Oncol. 2020;9:1547

42. Horn D, Gottlieb A. Algorithm for data clustering in pattern recognition problems based on quantum mechanics. Phys Rev Lett. 2002;88:018702

43. Weinstein M, Horn D. Dynamic quantum clustering: a method for visual exploration of structures in data. Phys Rev E 2009;80:066117

44. Sánchez J, Martín-Landrove M. A dynamic quantum clustering approach to brain tumor segmentation. arXiv:2107.07698v2 [physics.med-ph]; 2021

45. Sánchez J, Martín-Landrove M. Morphological and fractal properties of brain tumors. Front Physiol 2022;13:878391

46. Lafata K, Zhou Z, Liu J-G, Yin F-F. Data clustering based on Langevin annealing with a self-consistent potential. arXiv:1806.10597v1 [physics.comp-ph]; 2018

47. Kantelhardt JW, Zschiegner SA, Koscielny-Bunde E, Havlin S, Bunde A, Stanley HE. Multifractal detrended fluctuation analysis of nonstationary time series. Phys A Stat Mech Its Appl 2002;316:87–114

48. Lopes R, Betrouni N. Fractal and multifractal analysis: A review, Medical Image Analysis 2009;13:634–649

49. Gu G-F, Zhou W-X. Detrended fluctuation analysis for fractals and multifractals in higher dimensions. Phys Rev E 2006;74:061104

Acknowledgements

This research was supported by Universidad Central de Venezuela, INABIO, and Universidad Nacional Pedro Henríquez Ureña. We thank our colleagues from these institutions who provided insight and expertise that greatly assisted the research.

Author information

Authors and Affiliations

Faculty of Science and Technology, Physics Department, Universidad Nacional Pedro Henríquez Ureña, Santo Domingo, Dominican Republic

Jacksson Sánchez

Centre for Medical Visualization, National Institute for Bioengineering, INABIO, Universidad Central de Venezuela and Centro de Diagnóstico Docente Las Mercedes, Caracas, Venezuela

Miguel Martín-Landrove

Corresponding author

Correspondence to Miguel Martín-Landrove .

Editor information

Editors and Affiliations

Computational NeuroSurgery (CNS) Lab & Macquarie Neurosurgery Macquarie Medical School, Faculty of Medicine, Human and Health Sciences, Macquarie University, Sydney, NSW, Australia

Antonio Di Ieva

Rights and permissions

Reprints and permissions

Copyright information

About this chapter

Cite this chapter

Sánchez, J., Martín-Landrove, M. (2024). Multifractal Analysis of Brain Tumor Interface in Glioblastoma. In: Di Ieva, A. (eds) The Fractal Geometry of the Brain. Advances in Neurobiology, vol 36. Springer, Cham. https://doi.org/10.1007/978-3-031-47606-8_25

.RIS .ENW .BIB

DOI	Published	Publisher Name
https://doi.org/10.1007/978-3-031-47606-8_25	12 October 2023	Springer, Cham

Print ISBN	Online ISBN	eBook Packages
978-3-031-47605-1	978-3-031-47606-8	Biomedical and Life Sciences Biomedical and Life Sciences (R0)

Publish with us

Policies and ethics