

## Table of Contents

<b>Introduction</b> . . . . .	xi
<b>Chapter 1. A Fractal World</b> . . . . .	1
1.1. Fractals pervade into geography . . . . .	2
1.1.1. From geosciences to physical geography . . . . .	3
1.1.2. Urban geography: a big beneficiary . . . . .	6
1.2. Forms of fractal processes . . . . .	10
1.2.1. Some fractal forms that make use of the principle of allometry . . . . .	11
1.2.2. Time series and processes are also fractal . . . . .	12
1.2.3. Rank-size rules are generally fractal structures . . . . .	14
1.3. First reflections on the link between power laws and fractals . . . . .	14
1.3.1. Brief introduction into power laws. . . . .	15
1.3.2. Some power laws recognized before the fractal era . . . . .	17
1.4. Conclusion . . . . .	19
<b>Chapter 2. Auto-similar and Self-affine Fractals</b> . . . . .	21
2.1. The rarity of auto-similar terrestrial forms . . . . .	22
2.2. Yet more classes of self-affine fractal forms and processes . . . . .	24
2.2.1. Brownian, fractional Brownian and multi-fractional Brownian motion . . . . .	25
2.2.2. Lévy models . . . . .	32
2.2.3. Four examples of generalizations for simulating realistic forms . . . . .	35
2.3. Conclusion . . . . .	37

<b>Chapter 3. From the Fractal Dimension to Multifractal Spectrums . . . . .</b>	<b>39</b>
3.1. Two extensions of the fractal dimension: lacunarity and codimension . . . . .	40
3.1.1. Some territorial textures differentiated by their lacunarity. . . . .	40
3.1.2. Codimension as a relative fractal dimension . . . . .	41
3.2. Some corrections to the power laws: semifractals, parabolic fractals and log-periodic distributions . . . . .	43
3.2.1. Semifractals and double or truncated Pareto distributions . . . . .	43
3.2.2. The parabolic fractal model. . . . .	45
3.2.3. Log-periodic distributions. . . . .	46
3.3. A routine technique in medical imaging: fractal scanning . . . . .	48
3.4. Multifractals used to describe all the irregularities of a set defined by measurement . . . . .	50
3.4.1. Definition and characteristics of a multifractal . . . . .	50
3.4.2. Two functions to interpret: generalized dimension spectrum and singularity spectrum . . . . .	52
3.4.3. An approach that is classical in geosciences but exceptional in social sciences . . . . .	54
3.4.4. Three potential generalizations . . . . .	56
3.5. Conclusion . . . . .	57
<b>Chapter 4. Calculation and Interpretation of Fractal Dimensions . . . . .</b>	<b>59</b>
4.1. Test data representing three categories of fractals: black and white maps, grayscale Landsat images and pluviometric chronicle series . . . . .	60
4.2. A first incontrovertible stage: determination of the fractal class of the geographical phenomenon studied . . . . .	62
4.2.1. Successive tests using Fourier or wavelet decompositions. . . . .	63
4.2.2. Decadal rainfall in Barcelona and Beirut are fractional Gaussian noise . . . . .	73
4.3. Some algorithms for the calculation of the fractal dimensions of auto-similar objects . . . . .	75
4.3.1. Box counting, information and area measurement dimensions for auto-similar objects . . . . .	75
4.3.2. A geographically inconclusive application from perception. . . . .	78
4.4. The fractal dimensions of objects and self-affine processes . . . . .	80
4.4.1. A multitude of algorithms . . . . .	80
4.4.2. High irregularity of decadal rainfall for Barcelona and Beirut . . . . .	84
4.5. Conclusion . . . . .	85

<b>Chapter 5. The Fractal Dimensions of Rank-size Distributions</b> . . . . .	87
5.1. Three test series: rainfall heights, urban hierarchies and attendance figures for major French museums . . . . .	88
5.2. The equivalence of the Zipf, Pareto and Power laws . . . . .	89
5.3. Three strategies for adjusting the rank-size distribution curve . . . . .	92
5.3.1. A visual approach using graphs . . . . .	92
5.3.2. Adjusting the only linear part of the curve . . . . .	95
5.3.3. Choosing the best adjustment, and therefore the most pertinent law . . . . .	96
5.3.4. Which rank-size distribution should be used for Italian towns, the main French agglomerations and all French communes? . . . . .	98
5.4. Conclusion . . . . .	101
 <b>Chapter 6. Calculation and Interpretation of Multifractal Spectrums</b> . . . . .	 103
6.1. Three data sets for testing multifractality: a chronicle series, a rank-size distribution and satellite images . . . . .	104
6.2. Distinguishing multifractal and monofractal phenomena . . . . .	104
6.2.1. An initial imperfect visual test . . . . .	105
6.2.2. A second statistical test: generalized correlation dimensions . . . . .	107
6.3. Various algorithms for calculation of the singularity spectrum . . . . .	111
6.3.1. Generalized box-counting and variogram methods . . . . .	111
6.3.2. Methods derived from wavelet treatment . . . . .	112
6.3.3. Interpretation of singularity spectrums . . . . .	113
6.4. Possible generalizations of the multifractal approach . . . . .	116
6.5. Conclusion . . . . .	118
 <b>Chapter 7. Geographical Explanation of Fractal Forms and Dynamics</b> . . . . .	 121
7.1. Turbulence generates fractal perturbations and multifractal pluviometric fields . . . . .	122
7.2. The fractality of natural hazards and catastrophic impacts . . . . .	126
7.3. Other explanations from fields of physical geography . . . . .	128
7.4. A new geography of populations . . . . .	129
7.5. Harmonization of town growth distributions . . . . .	131
7.6. Development and urban hierarchies . . . . .	132
7.7. Understanding the formation of communication and social networks . . . . .	136
7.8. Conclusion . . . . .	137

<b>Chapter 8. Using Complexity Theory to Explain a Fractal World</b> . . . . .	139
8.1. A bottomless pit debate . . . . .	140
8.2. General mechanisms for explaining power laws . . . . .	143
8.3. Four theories on fractal universality . . . . .	144
8.3.1. Critical self-organization theory . . . . .	144
8.3.2. Béjan's constructal theory . . . . .	151
8.3.3. Nottale's scale relativity theory . . . . .	153
8.3.4. A general theory of morphogenesis . . . . .	154
8.3.5. Chaos and fractal analysis theory . . . . .	163
8.4. Conclusion . . . . .	164
<b>Chapter 9. Land-use Planning and Managing a Fractal Environment</b> . . . . .	167
9.1. Fractals, extreme values and risk . . . . .	168
9.1.1. Under-estimated hazards in preliminary risk assessments . . . . .	168
9.1.2. Fractal networks, fighting epidemics and Internet breakdowns . . . . .	171
9.2. Fractals, segmentation and identification of objects in image processing. . . . .	173
9.2.1. New image processing tools . . . . .	173
9.2.2. Some little-used fractal approaches using a GIS. . . . .	177
9.3. Fractals, optimization and land management . . . . .	177
9.4. Fractal beauty and landscaping . . . . .	179
9.5. Conclusion . . . . .	180
<b>Conclusion</b> . . . . .	183
C.1. Some tools and methods for quantifying and qualifying multiscale coarseness and irregularity . . . . .	184
C.2. A recap on geographical irregularities and disparities . . . . .	186
C.3. A paradigm that gives rise to new land-use management practices . . . . .	189
<b>Appendices</b> . . . . .	191
A.1. Preliminary thoughts on fractal analysis software . . . . .	191
A.2. Instructions for the following programs . . . . .	192
A.3. Software programs for the visual approach of a satellite or cartographic series or image . . . . .	193
A.4. Software programs for calculating fractal dimensions for a chronicle or frequency series . . . . .	198
A.5. Software programs for calculating the fractal dimensions of a satellite image or map. . . . .	208

A.6. Software programs for calculating multifractal spectrums of a series and an image . . . . .	213
<b>Bibliography</b> . . . . .	221
<b>Index</b> . . . . .	239