

Table of Contents

Preface	3
Table of Contents.....	11
Index of Tables.....	16
Index of Figures	17
Introduction.....	25
UN-SPIDER	25
GMES – observing our planet for a safer world	28
Intelligent data processing in GMES	29
Discussion	35
PART I. Practical Aspects.....	39
1 Managing Risk and Safety	41
1.1 The natural collapses	41
1.2 The technogenic collapses.....	45
1.3 The information collapses	47
1.4 Prediction of natural collapses	50
1.5 Rapid multi-sensor system for effective risk analyses.....	51
1.6 Network protection – policy and technology reinforcements.....	56
1.7 Intrusion detection systems	62
1.8 User-oriented policy for managing risk and safety	64
1.9 Discussion	73
2 High-performance Intelligent Computations for Environmental and Disaster Monitoring.....	76
2.1 Specifics of Earth observation problems.....	76
2.2 Existing tendencies and initiatives.....	78

2.3	Data assimilation approach	82
2.4	Applications	87
2.5	Levels of integration: main problems and possible solutions.....	97
2.6	Implementation: lessons learned	101
3	Investigation of Geodynamics of Central and Eastern Europe, Balkan Peninsula and Bulgaria	104
3.1	Introduction	104
3.2	General information about the investigations of the global geodynamics in the context of Central and Eastern Europe and the Balkan Peninsula.....	105
3.3	Geodynamic investigations of CEE.....	106
3.4	Geodynamic investigations of BP	108
3.5	Geodynamics of Bulgaria.....	115
3.6	Discussion	120
4	Intelligent Tools for Environment Monitoring: Features and Applications.....	121
4.1	Introduction	121
4.2	Measurement methods and structures	122
4.3	Portable device "Floratest" for express-diagnostics of photosynthesis.....	127
4.4	Discussion	134
5	Intelligent Gamma-Ray Data Processing for Environmental Monitoring.....	136
5.1	Introduction: gamma-ray spectroscopy for environmental monitoring and security	136
5.2	A machine learning approach to multi-channel gamma-ray spectroscopy.....	137
5.3	Machine learning with regularization for airborne gamma-ray surveying.....	147
5.4	Discussion	156
6	Acquisition, Processing and Analysis of Space Images at Risks Management of Natural and Technogenic Emergencies.....	158
6.1	Base principles of automation for risks emergency management.....	158
6.2	Satellite imagery for Earth's surface monitoring.....	162
6.3	Analysis of information capability of aerospace Earth monitoring data.....	171
6.4	Object detection at areas conducive to accident	174
6.5	The main gas-transport system as object of complex remote space monitoring	181
6.6	Discussion	185

PART II. Theoretical Aspects.....	187
7 Elaboration of Geoinformation Regional Monitoring Environmental System ("GERMES-I") Enriched by Artificial Intelligence Instruments	189
7.1 Introduction	189
7.2 Brief system description.....	190
7.3 Some examples of practical MCW monitoring and risk assessment.....	193
7.4 Artificial intelligence approach proposed and main principles of estimating/classifying model creation.....	197
7.5 Decision making rules for situations both with independent and dependent features.....	202
7.6 Examples of intellectual data processing application in Bulgarian Expedition (2007)	207
7.7 Carrying platforms and some new technical points	212
7.8 Discussion	215
8 Microsituation Concept in GMES Decision Support Systems.....	217
8.1 Situational modeling for decision making in emergent situations	217
8.2 Microsituation as a base part of risks management in risks management of possible snow avalanches	219
8.3 Microsituation as a base for comparative analysis of financial flows.....	228
9 Methods and Means for Protection of Software Critical Infrastructures.....	239
9.1 Definitions	239
9.2 The current situation.....	240
9.3 Available information for accomplished attacks.....	246
9.4 Methods of prevention, protection and recovery.....	249
9.5 Assessments.....	256
9.6 Discussion	257
10 The MLRP-method for Analysis of Some Problems in Climate and Seismology	258
10.1 Introduction	258
10.2 MLRP-method of creating logical-and-probabilistic model	260
10.3 Application MLRP-method to prediction multivariate time series problem	266
10.4 Application MLRP-method to prediction multivariate time series problem	268
10.5 Discussion	276

11	Polyhedral Coherent Risk Measures and their Application to Investment Decisions Support under Catastrophic Flood Risks	277
11.1	Introduction and some definitions	277
11.2	Models of support of optimal portfolio decisions on return-risk ratio in conditions of risk (known distributions)	280
11.3	PCRM in conditions of partial uncertainty	282
11.4	Models of support of optimal portfolio solution in conditions of partial uncertainty (incomplete information on scenario probabilities).....	284
11.5	Decision making on investments allocation under catastrophic flood risks	287
12	Techniques for Robust Bayesian Estimation	300
12.1	Introduction	300
12.2	Methods of estimating parameters in risk models based on classical sampling theory	304
12.3	Bayesian approach to parameters estimation. Analysis and methods of investigation	305
12.4	Statement of the problem of robust estimating reliability parameters	311
12.5	Statement of the problem of seeking lower and upper bounds for Bayesian estimates of reliability parameters.....	313
12.6	Classes of distributions.....	316
12.7	Discussion	317
13	Application of Information Theories to Safety of Nuclear Power Plants	318
13.1	Introduction	318
13.2	Review of main information theories and interpretations.....	319
13.3	A proposal on how some information theories and interpretations can be applied to safety of nuclear plants	322
13.4	Discussion	325
	PART III. Technological Aspects.....	327
14	Growing Pyramidal Networks	329
14.1	Intelligent systems memory structuring	329
14.2	Pyramidal networks	334
14.3	Program complex CONFOR.....	340
14.4	Discussion	345

15 Multi-dimensional Information Spaces as Memory Structures for Intelligent Data Processing in GMES	347
15.1 Memory management.....	347
15.2 Access methods.....	348
15.3 Multi-dimensional numbered information spaces.....	353
15.4 Discussion	359
15.5 Data mining analysis environment "PaGaNe"	360
15.6 CAR algorithm MPGN	360
15.7 Discussion	370
 Conclusion	 371
 Bibliography	 373
 Authors' Information	 399

Index of Tables

Table 1. MIRAMAP Multi-Sensor Specifications.....	52
Table 2. BULiPOS services.....	119
Table 3. Relative error of ^{137}Cs activity in the multi-nuclide sample obtained by ROI, STR, MPCR.....	144
Table 4. The signal reconstruction error for the discrete ill-posed problem of gamma-surveying obtained by the regularization methods without and with random projecting. K is the dimensionality of projection matrix.	155
Table 5. Probabilities of correspondence of the current parameters of avalanche climate initiation medium to the avalanche dangerous and avalanche non-dangerous situations.....	221
Table 6. Results of forecasting of avalanche-dangerous and avalanche-safe situations	223
Table 7. Wilcoxon test value.....	224
Table 8. Integral Wilcoxon test values.....	225
Table 9. Groups of objects that are most often subject to information attacks.....	244
Table 10. Percentage distribution of accomplished attacks by structures for each attack's group.....	247
Table 11. Results from training process of MPGN for Forestfires data set	366
Table 12. Results of recognition for Forestfires data set with MPGN and WEKA classifiers.....	368

Index of Figures

Figure 1. Ash concentration on April 17, 2010 [Metoffice, 2010].....	45
Figure 2. Engine room Sayano-Shushenskaya power plant before (left) and after (right) the accident (www.lhp.rushydro.ru).....	46
Figure 3. Earthquake (a) not observed; (b) discovered; (c) 30th second after the first jolt (the red lines show the region of wave propagation).....	51
Figure 4. MIRAMAP multi-sensor aircraft	53
Figure 5. MIRAMAP soil moisture scanner	53
Figure 6. Project locations in Bulgaria	54
Figure 7. Water seepage at Danube river	54
Figure 8. Soil moisture under dry condition.....	54
Figure 9. Soil moisture under wet condition.....	54
Figure 10. 10-cm Orthophoto for LPIS	55
Figure 11. Lidar elevation model for GAEC	55
Figure 12. 3-D Fly-through of orthophoto and Lidar elevation	55
Figure 13. Multi-sensor composite	55
Figure 14. SPARTA architecture.....	58
Figure 15. SPARTA implementation	59
Figure 16. SARM's branch organization in Kapan	60
Figure 17. Scheme of the SPARTA technical environment for independent verification and validation tasks	60
Figure 18. SPARTA data analysis module architecture.....	61
Figure 19. Architecture of an intrusion detection system [Galatenko, 1999].....	63
Figure 20. Simplified technology for seismic damage assessment of dwellings.....	68
Figure 21. GEMITIS' seismic risk analysis	69
Figure 22. Non-linear, non-proportionate (as set against that of housing) increase of damage	72
Figure 23. European network of application servers for analyses and risk monitoring	75
Figure 24. European network of regional units for risk and security management, land cover changes monitoring and data quality assurance	75
Figure 25. Common services and models for a variety of applications	77
Figure 26. Overall data flowchart at Ukrainian segment of GEOSS/GMES	83

Figure 27. UML sequence diagram [Larman, 2004] for the NWP application	88
Figure 28. The example of land temperature forecasts using WRF model.....	89
Figure 29. The results of WRF performance on the SCIT-3 cluster: computation time for 1 iteration (left); acceleration of the WRF model with respect to a number of nodes (right)	89
Figure 30. SAR image acquired from RADARSAT-2 satellite during the flood on the river Norman, Australia(14.02.2009)	91
Figure 31. Flood mapping from SAR satellite imagery: workflow	92
Figure 32. The resulting flood extent shown with white color for the river Norman, Australia (RADARSAT).....	93
Figure 33. a) scatter plot of estimated leaf moisture C_w' and true C_w ; b) dependency of estimate of standard deviation of leaf moisture $\sigma(d,w)$ w.r.t. real leaf moisture C_w	96
Figure 34. a) scatter plot of estimated leaf moisture C_w' and true C_w ; b) histogram of normalized errors δ	97
Figure 35. Data integration level	98
Figure 36. Task management level.....	98
Figure 37. Portal approach to grid system integration	99
Figure 38. Metascheduler approach	100
Figure 39. Three-level architecture of Wide Area Grid (WAG)	100
Figure 40. User interface of WAG geoinformation system	101
Figure 41. Architecture of satellite monitoring system integration.....	102
Figure 42. OpenLayers interface to multiple data.....	102
Figure 43. InterGrid architecture	102
Figure 44. Global UN-SPIDER flood monitoring and risk assessment system	103
Figure 45. Simplified sketch of main tectonic plates and sub-plates in the Mediterranean area [Plag et al, 1998]	105
Figure 46. Horizontal velocity estimations from reprocessed time series of CEGRN campaigns 1994-2007	107
Figure 47. Horizontal velocity estimations from cumulated weekly time series of CERGOP permanent sites 1999-2008.....	107
Figure 48. Active processes in the Eastern Mediterranean (based on [Carminati et al, 2004])	108
Figure 49. Balkan Peninsula CEGRN sub-network stations	111
Figure 50. Balkan Peninsula permanent stations.....	112
Figure 51. Station velocity differences between results of this study and estimations from IGS/EPN/CEGRN	113
Figure 52. The monograph "Geodynamics of the Balkan Peninsula"	114
Figure 53. Hazard map for a 1000-year return period	115
Figure 54. Bulgarian stations participated in CEGRN03 campaign.....	116

Figure 55. Bulgarian stations participated in CEGRN05 campaign.....	116
Figure 56. GPS and NNR-NUVEL1A velocity vectors of BULREF stations	117
Figure 57. GPS station velocities in south-west Bulgaria	117
Figure 58. BULiPOS DGNSS stations	118
Figure 59. Multichannel device for field measurements	123
Figure 60. An IR thermometer for field measurements.....	123
Figure 61. Cotton canopy temperature map on 12:00, based on infrared measurements on the field.....	123
Figure 62. Soil moisture map of the soil surface of the cotton field.....	123
Figure 63. Structure of a satellite station of ARAX system.....	124
Figure 64. Block diagram of the microcomputer measurement system structure.....	125
Figure 65. Diurnal curves of the evapotranspiration and other heat balance elements registered by one local station of the system in the Razgrad region	125
Figure 66. Chlorophyll fluorescence induction curve.....	128
Figure 67. Appearance of portable device "Floratest"	129
Figure 68. Functional diagram of portable device "Floratest"	130
Figure 69. Integrated algorithm of device work and proper models.....	131
Figure 70. Data acquiring, processing and transmitting system on the base of portable device with radio channel	131
Figure 71. The sensor of the "Floratest" on the vine leaf	132
Figure 72. The image of CFI on the device's display.....	132
Figure 73. CFI intensity of vine plant (sort PxP 101-14) under drought and normal conditions	133
Figure 74. CFI intensity of vine plant (Kober 5BB) under drought and normal conditions	133
Figure 75. Chlorine content in researched trees' leaf.....	134
Figure 76. Readouts for researched trees.....	134
Figure 77. Measuring chlorophyll fluorescence induction curve	134
Figure 78. Multi-channel spectrometer "Vector".....	138
Figure 79. Detector response functions (200 functions of 256 channels each.....	139
Figure 80. Spectrum decomposition using detector response functions	139
Figure 81. Regions-of-Interest and Full Spectrum approaches to gamma-ray spectroscopy	140
Figure 82. Gamma-ray spectroscopy by machine learning.....	141
Figure 83. Detector response functions of the true model.....	144
Figure 84. Radionuclide activity error vs noise level for various models and model selection criteria.....	145
Figure 85. The results of gamma-ray spectra measurements by 3 detectors. ^{137}Cs , ^{40}K , and are mixed in the spectra	146
Figure 86. Independent components separated from the spectrum mixtures: ^{137}Cs , K^{40} , and background	146

Figure 87. Onboard airborne gamma-ray system	148
Figure 88. The surface density function (left) and its measurements (right)	149
Figure 89. Deconvolution and regularization machine learning approaches to airborne gamma-ray surveying	150
Figure 90. The kernel matrix Φ for gamma-ray surveying	154
Figure 91. The modeled 1D surface density x , the measurement y , and the restored density x^* for gamma-ray surveying	154
Figure 92. Dependence of the signal reconstruction error e_{pinQR} (left Y-axis) and gMDL values (right Y-axis) on the dimensionality K of the projection matrix at the noise levels 10^{-2} , 10^{-6} , 10^{-10} . Minima are at close K	155
Figure 93. The computation times of pseudo-inverse solutions vs K : Pinv – ordinary, R+Pinv – with random projection, QR+Pinv – random projection orthogonalized	156
Figure 94. General technological scheme of remote space monitoring	161
Figure 95. The principle of UAVcontrol with the use of DIS.....	166
Figure 96. Images synthesized by DIS	166
Figure 97. DIS structure.....	167
Figure 98. Graphic processing unit structure chart.....	170
Figure 99. The overlapping of a terrain images made from the moving satellite.....	175
Figure 100. Point matching of the stereo pair of satellite images	176
Figure 101. Neighborhood for m-rate of function of curvature of contour curve.....	178
Figure 102. Neighborhood of sectoral m-rate of function of curvature of contour curve	178
Figure 103. An image from QuickBird satellite - a corridor of the gas main pipeline	183
Figure 104. An image from Quick Bird satellite - gas-compression station	183
Figure 105. Automatic revealing of not authorised building in a security zone of the main gas pipeline with use of program complex ENVI.....	184
Figure 106. Preliminary version of GERMES-I structure.....	192
Figure 107. Scanning and non-scanning MCW-radiometers ready to work	194
Figure 108. Thin oil-film recognition in Odessa harbor (end of 80s).....	194
Figure 109. Map of underground water, Middle Asia (early 80s)	194
Figure 110. Illustration of surface state (a) and underground water table (b) measured in different bands (red and yellow colors indicate dry surface).....	195
Figure 111. Experimental comparison of contact and remotely sensed data. Upper Part: changes in emissivity at the wavelengths of 2 cm(1) and 30 cm (2) Lower Part: "in situ" data of the depth to water table.....	195
Figure 112. MCW monitoring in the region of Mississippi and Ohio Rivers, USA, end of 90s	195
Figure 113. The complex (synthesized) pictures: left – area of water seepage detection in the Netherlands, 2005; right – forest fire in Bulgaria, 2007	196
Figure 114. Satellite multispectral picture of Mexican Gulf coastline	196

Figure 115. Thematic maps obtained by MCW remotely sensed data	196
Figure 116. Mexican Gulf coastline synthesized picture, end of 90s	197
Figure 117. Presentation of vector assessment model	198
Figure 118. Relation between requirements (Vs) and features (S).....	200
Figure 119. Creation of the memory (1 st stage)	203
Figure 120. Second learning stage	204
Figure 121. Using the probability distribution curves for advanced decision.....	206
Figure 122. Structure of mouse memory belonging to the vibrissa's information	206
Figure 123. The dam nearby village of Nikolovo (from plane)	208
Figure 124. MCW maps with data measurements at the Nikolovo area for various conditions	209
Figure 125. Situation with Nikolovo dam and area humidity after a rainfall	210
Figure 126. Illustration of use both aim-oriented vector model and advanced decision rules (assessment of dam effectiveness).....	210
Figure 127. Infrared photograph of the woodland with two control areas – A and B.....	211
Figure 128. Preliminary assessment of forest fire danger for locations A (high risk) and B (low risk).....	211
Figure 129. Final assessment of forest fire danger for locations A (high risk) and B (low risk)	211
Figure 130. Illustration of various mobile earth and air platform.....	212
Figure 131. Comparison of remote sensed soil moisture with in situ data in 0-1 cm, 0-3 cm and 0-6 cm layer	213
Figure 132. "Flying MCW Laboratory (a) and allocation of special antennas on the airplane (b)	213
Figure 133. Ranet 21, the newest 21-cm radiometer design by Vega Radio Corporation.....	214
Figure 134. Example of dual-frequency spaceborne radar with synthetic aperture	214
Figure 135. Example of high resolution spaceborne radar with synthetic aperture	214
Figure 136. Generalization of separate situations of prototype system.....	217
Figure 137. On the explanation of the probabilistic aspect of the avalanche climate initiation medium analysis	221
Figure 138. Position of microsituations in situations space	225
Figure 139. Probability distribution for 1-st version	226
Figure 140. Probability distribution for 2-nd choice	226
Figure 141. Probability distribution for 3-rd choice	227
Figure 142. Probability distribution for 4-th choice	227
Figure 143. Methods of the fuzzy sets theory as the basis for correction of the prediction system time response to the possible avalanche descent	227
Figure 144. Dynamics of EMBI+ index change for several countries	229
Figure 145. Density of profitability distributions of some Ukrainian indexes.....	229

Figure 146. Generalized structure of process forming knowledge base in decision support system based on analysis of different financial flows, characterizing separate microsituations	230
Figure 147. The specific weight dynamics of the granted credits to the total assets volume in the banking system as a whole during the period from 01.01.2004 till 01.05.2008.....	234
Figure 148. Consistency of microsituations representing variation of the credits specific weight in the banks assets volume according to the results of the banking system work	235
Figure 149. Consistency of microsituations representing variation of the credits specific weight in the banks assets volume according to separate banks of the group being studied by the results of their work within the period from 01.01.2004 till 01.05.2008.....	235
Figure 150. Phase portraits of data series defining bank's activities on the market of interbank loans for 2004-2008 (monthly)	237
Figure 151. Main operations applied on file objects.....	240
Figure 152. Main categories information attacks	241
Figure 153. An object in environment without method of protection	241
Figure 154. An object in environment with method of protection.....	241
Figure 155. Main categories methods of protection	241
Figure 156. Main protection's groups	244
Figure 157. Percentage distribution of accomplished attacks' groups	246
Figure 158. Percentage distribution of attacks' groups, accomplished to computers, systems and networks with respect to the separate structures	247
Figure 159. Comparison of the percentage distribution of single category's attacks with respect to the single structures with overall percentage distribution of accomplished attacks to separate structures.....	247
Figure 160. Percentage distribution of accomplished attacks groups to the Software Critical Infrastructures with respect to the objects' groups	249
Figure 161. Percentage distribution of accomplished attacks groups to the Critical Infrastructures with respect to the objects' groups	249
Figure 162. Percentage distribution of accomplished attacks groups to the Critical Infrastructures	249
Figure 163. Analysis univariate time series	267
Figure 164. Two dependent time series.....	268
Figure 165. The decision tree of hydrological situations	271
Figure 166. First decision tree of meteorological situations.....	273
Figure 167. Second decision tree of meteorological situations	273
Figure 168. Functions "moment of flooding – yield losses"	293
Figure 169. Graphs of percent property losses dependent on structure inundation depth	293
Figure 170. The look of the decision support system interface	299
Figure 171. Pyramidal network building	335

Figure 172. Forming of pyramidal growing network – rule B1	338
Figure 173. Forming of pyramidal growing network – rule B2	338
Figure 174. The structure of program system CONFOR.....	340
Figure 175. Genesis of the Access Methods and their modifications extended variant of [Gaede and Günther, 1998] and [Mokbel et al, 2003] presented in [Markov et al, 2008]	349
Figure 176. Taxonomy of the Access Methods	350
Figure 177. The MPGN pruning algorithm	363
Figure 178. MPGN - Creating recognition set for one class	364
Figure 179. MPGN - Analyzing resulting recognition sets and making decision which class to be given as answer.....	365
Figure 180. Pyramid for Forestfires data set, class="No"	367
Figure 181. Pyramid for Forestfires data set, class="Fire"	367
Figure 182. Classification accuracy of Forestfires data set given by MPGN and selected Weka classifiers.....	369
Figure 183. The ratio between recognized instances from class "No" versus class "Fire"	369