Introduction

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Abstract Large scale natural disasters cause untold misery and massive damage to life, infrastructure and property. Such disasters, often categorised as geophysical (such as earthquakes, volcanic eruptions, tsunamis, landslides, snowdrifts and avalanches), hydrological (including floods, river and debris overflows), meteorological (hurricane, tropical storms, sandstorms, high winds, heavy rainfall), climatological (such as wild-fires, drought, extreme temperatures), lead to significant loss of life, damage to the living, human displacement and poverty and indeed to devastation of the foundations of cities, towns, villages and the countryside; and the associated damage to the infrastructure of roads, housing, buildings, bridges, communication systems and more. Victims are often trapped in collapsed buildings, without electricity, water or other means of communications. Thus the development and understanding of advanced techniques for disaster relief are of immense current interest, and there is a compelling need for effective disaster prediction, relief, and associated management systems and the development and understanding of advanced techniques for disaster relief are of immense current interest. Requirements for the enhancement of early warning and emergency response systems to geological disasters are of essential importance. To ensure speedy recovery of people and the protection of the national infrastructure threatened by natural disasters, real time detection and data collections are a necessary prerequisite. Threats become even more complex due to the evolution of geological disasters.

Keywords Geological disasters · Disaster monitoring · Networks

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Large scale natural disasters cause untold misery and massive damage to life, infrastructure and property. Such disasters, often categorised as geophysical (such as earthquakes, volcanic eruptions, tsunamis, landslides, snowdrifts and avalanches), hydrological including floods, river and debris overflows), meteorological (hurricane, tropical storms, sandstorms, high winds, heavy rainfall), climatological (such as wild-fires, drought, extreme temperatures), lead to significant loss of life, damage to the living, human displacement and poverty and indeed to devastation of the foundations of cities, towns, villages and the countryside; and the associated damage to the infrastructure of roads, housing, buildings, bridges, communication systems and more. Victims are often trapped in collapsed buildings, without electricity, water or means of communications. Thus there is a compelling need for effective disaster prediction, relief, and associated management systems, and the development and understanding of advanced techniques for disaster relief are of immense current interest. Requirements for the enhancement of early warning and emergency response systems to geological disasters are of essential importance. To ensure speedy recovery of people and the protection of the national infrastructure threatened by natural disasters, real time detection and data collection is a necessary prerequisite. Threats become even more complex due to the evolution of geological disasters.

Construction of geological condition monitoring sensor networks in areas prone to earthquakes, volcanoes, and landsides would provide information on geographical structural state changes through the real time online analysis of large scale sensor networks data. Such networks would also provide early warning of major geological disasters, reduce casualties and property losses.

To explore these areas of concern and to identify developments of new technologies for monitoring susceptible locations, an International Workshop was held in Harbin, China, from 14 to 17 July 2017, where some of the leading workers in the field presented their latest research findings. The Workshop was funded by the National Natural Science Foundation of China (NSFC) and the British Council under the Newton Researcher Links Programme.

The Workshop brought together some thirty early career researchers from China and the UK, with complementary skills in geosciences, electronics, wireless systems, and sensor networks. The objectives of the Workshop were to increase research capacity, encourage knowledge transfer from cognate areas, explore and identify opportunities for collaborative research, and build international teams for future collaboration in this area of international importance—disaster recovery and mitigation. The aim of the Workshop was to identify emerging areas of research in wireless sensor networks with high impact potential on disaster monitoring; addressing real world situations using advanced sensor and signal processing and communications technologies.

This monograph is the outcome of the proceedings of the Workshop. The Editors have carefully selected the most informative, challenging and original of the presentations, which have been further carefully nurtured by the authors for inclusion in this Monograph.

The Second Chapter by Heiderzadeh and Gusman et al. "Application of Dense Offshore Tsunami Observations from Ocean Bottom Pressure Gauges (OBPGs) for Tsunami Research and Early Warnings", covers a relatively new area in Disaster monitoring—that of Tsunami observations from deep Ocean Bottom Pressure Gauges (OBPGS), which offer new insights into tsunami characteristics. The authors present a procedure for extracting tsunami signals from OBPGs data, and then apply the procedure to two tsunami case studies to verify the efficacy of their approach and the value of the use of OBPG data towards tsunami research and warnings.

The follow-on Third Chapter by Novellino et al. "Remote Sensing for Natural or Man-Made Disasters and Environmental Changes", is concerned with the effective use of satellite remote sensing in supporting disaster management studies in areas affected by natural hazards. The authors contend that a key reason for the adoption of remote sensing is that it is one of the fastest means of acquiring data in a timely and cost effective manner, up to regional-scale during pre-disaster and post-disaster studies. Using three distinctive case studies from (i) the landslide inventory map of St. Lucia island, (ii) tsunami-induced damage along the Sendai coast (Japan) and (iii) the landslide geotechnical characterization in Papanice (Italy), the authors show recent advances in remote sensing, including the use of new spaceborne/airborne sensors and techniques, that offer a 'best practice' environment for the better management of geohazards.

The next two Chapters (Four and Five) "Classification of Post-Earthquake High Resolution Image Using Adaptive Dynamic Region Merging and Gravitational Self-organizing Maps" and "A Survey on the Role of Wireless Sensor Networks and IoT in Disaster Management" are complementary, in that they deal with the acquisition and handling of big data and its analysis, which in one case addresses the issue of disaster monitoring and recovery, and the other studies post-disaster issues confronting the management scenarios. The authors in Chapter Four "Classification of Post-Earthquake High Resolution Image Using Adaptive Dynamic Region Merging and Gravitational Self-organizing Maps" have addressed the important issue of the recognition of regions of similarity and dissimilarity needed to classify areas of common relevance following an earthquake. To this effect the authors describe their work as developing advanced segmentation tools for image processing using adaptive and dynamic region merging and combining these with sophisticated feature extraction techniques that rely on spectral and spatial feature textures to devise gravitational self-organizing maps (gSOM) that offer a novel object-based classification framework. The work is well illustrated by application to data and aerial seismic images from the Wenchuan earth quake of 2008 to demonstrate the effectiveness of the proposed techniques. The methods while conceptually advanced are computationally expensive.

Adeel et al., have conducted a review of emerging technologies for communications that aid disaster management, and have identified a range of instruments applicable to wireless sensor networks, including the use of 4G and 5G systems, and indeed the emerging technologies of the 'Internet of Things (IoT)' and the associated big data technologies. A valuable piece of work in the Chapter includes an evaluation of two major IoT standards; and a potential solution based on Cognitive 5G long range and low power sensor networks.

The Sixth chapter by Ilya Sianko et al., on "Modelling of Earthquake Hazard and Secondary Effects for Loss Assessment in Marmara (Turkey)", reports on the excellent work on 'Earthquake Risk Assessment' that has been conducted at the University of Sheffield. One of the most critical components in seismic risk assessment is the calculation of the hazard, and this Chapter proposes tools for determining earthquake hazards, especially for regions with limited seismo-tectonic information. They have developed a seismic hazard analysis tool, based on probabilistic modelling, which generates synthetic earthquakes using a Monte Carlo approach; and have carried out a case study on the area of Marmara in Turkey to validate the effectiveness of the tool.

In the Seventh Chapter "Unmanned Aerial Vehicles for Disaster Management", Lou et al., present a comprehensive study of the use of Unmanned Aerial Vehicles (UAVs) as an effective strategy for disaster management and response, in practical environments. Basing their work on the premise that UAVs can be easily deployed and can reach inaccessible locations, they make a compelling case for the deployment of UAVs to map out affected areas in a relatively short time; and aiding a swift and efficient response to a disaster by providing accurate hazard maps, in high resolution and in real time, as an effective guide to the rescuer to assess the situation, make relief plans and conduct rescue.

They analyse networked architecture for multiple UAVs, which represents an enhanced and efficient network-assisted disaster management system that involves data collection, victim localisation and rescue optimisation. They introduce a universal networked architecture that integrates WiFi, cellular, self-managed UAV ad hoc and satellite networks, to offer easy and fast-to-deploy, flexible, and inexpensive technology to coordinate the rescue teams in the case of disastrous events and to help the survivors in a timely manner. The authors address the associated design and system performance challenges, and include heuristic algorithms for placing UAV nodes to facilitate reliable communications to disconnected groups.

The Eighth chapter on "Human Detection based on Radar Sensor Network in Natural Disaster" by Wei WANG, exploits the use of Ultra-Wideband (UWB) radar technology as a means of detecting humans in disaster affected regions. The premise is based on the ability of UWB radars to penetrate through walls and thus locate humans. UWB systems have been developed using synthetic aperture radar that offer penetration ability and high resolution imaging of hidden 'targets'; and associated Doppler radar systems identifying the presence of human beings by detecting respiratory—induced Doppler signals and human movements.

This Chapter sets the scene by developing the tools based on fuzzy pattern recognition and genetic algorithms for identifying multiple status of human beings from UWB radar returns, and conducting a comprehensive analysis to justify their use. This work is followed by a report on a detailed experiment using a P410 MRM radar device, to assess its performance under six different scenarios-including the through-wall no person status, normal breathing status of one person, swing arms status of one person, normal breathing status of two persons, walking 2 m away status of two persons and normal breathing status of three persons.

The results have a very important theoretical significance and practical value. The difference between the through-wall slow breathing status of three persons and the swing arms status is small, so there is the possibility of wrong judgment or false alarm. This chapter compares the fuzzy pattern recognition algorithm with current standards, and illustrates that the proposed algorithm is superior to the other three algorithms.

The Ninth Chapter on "Real-time Wind Velocity Monitoring based on Acoustic Tomography" introduces another facet of disaster monitoring—i.e. the monitoring of wind—related disasters, and introduces the development and performance of anemometers based on acoustic tomography. These utilise the dependence of sound speed on wind velocity as a promising remote sensing technique for wind velocity monitoring. The approach offers the advantage of being low cost, easy to implement, and non-invasive, i.e. not affecting the localised field.

Using elegant mathematics, the authors develop the theory for the reconstruction of the acoustic wave fields received on an array of acoustic sensors. On the assumption of linear wave fields, the authors use time of flight measurements along multiple ray paths, to develop a method of tomographic reconstruction of wind velocity fields. Using simulated data for three different velocity fields, the authors evaluate the performance of their reconstruction algorithm and show that acoustic tomography provides quality tomographic images of the velocity fields with good accuracy.

The Tenth Chapter on "Joint Optimization of Resource Allocation with Inter-beam Interference for a Multi-beam Satellite and Terrestrial Communication System" is concerned with the study of satellite and terrestrial communication systems in order to evaluate their performance during emergency scenarios depicted by natural disasters, and in providing satellite mobile services. The key concern is optimal resource allocation to conserve on-board resources and their utilisation. Here algorithms are developed to optimise joint bandwidth and power allocation, while taking into consideration the satellite inter-beam interference, channel condition and delay factors.

The work proposes an energy-efficient scheme, which integrates satellite-terrestrial spectrum sharing; based on three stages—firstly the central terrestrial cell receives an intensive signal offering a high signal-to-noise ratio based on a full frequency reuse scheme; secondly ranking the satellite beam isolation for different frequency bands corresponding to the base station/user location, and thirdly, dividing the highest degree of isolation band and the lowest isolation band into one group; the sub-high degree of isolation band and sub-low isolation band into other group and so on.

The authors show that in comparison with current algorithms that offer separate bandwidth or power optimal allocation, their proposed algorithm allocates resources flexibly according to specific traffic demand and channel condition. The authors propose a system model taking into consideration satellite beams, macro base station, remote radio heads and three layers cover that cause serious inter-layer interference. Based on this model, the authors carry out an interference analysis; and then propose an integrated satellite-terrestrial cognitive spectrum sharing scheme based on an exclusion zone, and an associated energy-efficient spectrum allocation scheme with high inter-cell fairness.

Through detailed simulation using realistic scenarios, the authors compare their results with conventional approaches to prove the effectiveness of their approach. They further take into consideration the power consumption model and then develop the joint resource allocation model and analyse this under several scenarios, such as matrix sparseness, water-filling, complexity and power consumption, and then carry out detailed simulation and performance to show that their algorithm outperforms conventional techniques in terms of energy efficiency and activity ratios.

The Eleventh chapter on "Intelligent Sub-meter Localization Based on OFDM Modulation Signal" is a comprehensive study of systems and techniques to be used to optimise Location Based Services (LBS), with associated localisation and navigation applications. While global navigation satellite systems are effective when LBS are sought outdoor, their performance deteriorates considerably in indoor environments; where accurate localisation is a necessity, as in indoor rescues, location of mines, or even finding items in shopping malls. The main contribution of this Chapter, is the design of a new precise indoor localization system based on the CSI (Channel State Information) which is available in many existing commodity Wi-Fi devices to estimate the AOA (Angle of Arrival) of the multipath signal. To overcome the limitation of the conventional AOA estimation approaches, the proposed method exploits the OFDM (Orthogonal Frequency Division Multiplexing) modulation property to estimate the AOA of the signal using a significantly reduced number of antennas, and with a small modification of hardware. To solve this problem, the authors propose the use of two-dimensional spatial smoothing for the AOA estimation with respect to the multiple correlated signals. The proposed system comprises three steps—CSI-based AOA estimation followed by direct signal path identification, and then Target localisation. This offers sub-meter accuracy. The Chapter includes extensive derivation of the associated algorithms, clear justification of the approaches taken, and detailed simulations carried out along with assessment on experimental set ups to evaluate the performance of the proposed approach and compare it with conventional techniques to show the benefits offered by the authors work. The proposed system can be easily implemented on future 5G networks, and LTE (Long-Term Evolution) which is a standard for high-speed wireless communication for mobile devices and data terminals, with advantages of MIMO antennas.

The Twelfth Chapter give an overview of the broad conclusions of the work reported in the earlier chapters, and offers some final comments and observations by the Editors.The Editors would like to thank the Chapter authors and their co-authors for their cooperation, their hard work, and for contributing their insight and experiences to this monograph; and to all the attendees of the Workshop on 'GEOLOGICAL DISASTER MONITORING BASED ON SENSOR NETWORKS held in Harbin in July 2017; and indeed to the sponsors—The National Natural Science Foundation of China and the British Council Researcher Links Programme supported by the Newton Fund.