Conclusions and Final Comments

Tariq S. Durrani, Wei Wang and Sheila M Forbes

This monographs is based on Chapters provided by experts from UK and China who had attendees an NSFC Newton Researcher Links Workshop held in Harbin in July 2017, and records the results of their latest research. With the objective of exploring emerging techniques in monitoring natural disasters, and associate mitigation activities, this monograph highlights a range of techniques for the purpose.

Each of the chapters covers the introduction of a specific monitoring technique, collection of data and the related analysis of the proposed technique to reflect performance in adverse circumstances. The First Chapter gives a broad introduction to the monograph. The Second Chapter explores the use of Ocean Bottom Pressure Gauges, attached to Ocean Bottom Seismometers, to establish a warning system for tsunamis, and specifically to observe the onset and occurrence of tsunamis, and offer new insights. This is a new approach to tsunami observations and compares favourably with the conventional technique of the DART (Deepwater Assessment and Reporting) approach; and offers two specific advantages—with a more dense installation than DARTs, they offer high spatial resolution coverage, and higher frequency resolution, due to the higher sampling rates, though they lead to a requirment of assessing a larger quantity of data. The authors have proposed new procedures for data collection and handling and then applied these to observations from two tsunamis to show the effectiveness of their approach.

T. S. Durrani (✉) · S. M. Forbes
University of Strathclyde, Glasgow, Scotland, UK
e-mail: durrani@strath.ac.uk

S. M. Forbes
e-mail: sheila.forbes@strath.ac.uk

W. Wang
Tianjin Normal University, Tianjin, People's Republic of China
e-mail: weiwang@tjnu.edu.cn

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The Third Chapter presented by a team mostly from the British Geological Survey, with partners in Florence, Italy; study the efficacy of satellite remote sensing in three diverse case of hazards—landslide inventory, tsunami induced damage, and geotechnical characterisation of a landslide in Italy.

In the case of the landslide inventory for the island of St. Lucia, the authors show the efficacy of Earth Observation Satellite data over land use surveys, and offer further insights into landscape response triggered by such hurricanes; and are vital in establishing relevant hazard and risk assessments. In the second case, the authors studied landslides in a small hamlet in Italy—Papanice, as a consequence of a severe rainfall. The lanslides were remotely monitored by means of multi-temporal InSAR, which provided ground displacement estimates at millimetre precision from TerraSAR-X images, integrated with other data to obtain a complete characterisation of the landslides. Interestingly, the integration of remote sensing and traditional geological/geotechnical investigations has suggested the installation of a superficial drainage system as the best intervention to mitigate the risk. The third case was a study of the most powerful Tsunami to affect Japan, in March 2011, and its impact near Sendai Airport. Using multi-temporal high-resolution satellite data, the researchers assessed the tsunami impact on the coast, as well as mapped the spatio-temporal trajectories of damage and reconstruction activities in the area. The work verified the value of the new (Earth Observation Satellites) spaceborne/airborne sensors and techniques developed in the last ten years, complemented by computational resources for running large-scale model simulations, leading to the development of 'best-practice' environmental information which enables planners to better manage geohazards.

The Fourth Chapter addressed the issue of rapid mapping of damages and damage assessment by proposing novel image segmentation and classification techniques. In particular the method combined advance image processing and pattern recognition techniques based on Adaptive Region Monitoring and Gravitational Self organising maps, to identify spectral textures and dynamically merging regions to classify cognate regions. These techniques create damage maps or detect and localize damage objects, delivering 'boundary-closed and spatial-continuous regions'. The algorithms were tested on real data from the Wenchuan Earthquake in China, and the work illustrated how inaccurate classification of regions can be avoided. The techniques are computing intensive and require significant segments of data, though the authors hold out the prospect of using 'deep learning' to overcome the above issues, and extend the work to multi-spectral and hyperspectral data.

The Fifth Chapter studied issues concerned with the deployment of Sensor Networks to monitor disasters and manage disaster regions. The authors conducted a review of current and emerging wireless communications technologies and associated IoT (Internet of Things) protocols to identify current approaches to Disaster Sensing and Monitoring. They posit that Wireless Sensor Networks, employing low energy sensor nodes capable of measuring and recording environmental conditions, exploiting 5G and emerging technologies, could be developed as intelligent and interconnected infrastructures to yield huge amounts of data, and combined with artificial intelligence would form the basis of the next generation of intelligent disaster management systems. The authors have studied the current IOT Standards LoRa/4G LTE and identified their limitations, and recommend that future work should focus on "developing robust fair data rate allocation and power control methods to address existing LoRa limitations and acquire optimised airtime, data rate, and energy consumption".

An important aspect of Disaster Management is the availability of tools which offer facilitation and assessment of risks and hazards. To this effect the Sixth Chapter is concerned with a new Earthquake Risk Assessment tool which is particularly applicable to regions with limited seismotectonic data—a not uncommon scenario. The team from the University of Sheffield has exploited a probabilistic framework to develop a methodology which utilises Monte Carlo techniques to simulate key hazard parameters such as magnitude, epicentre location, depth of hypocentre, and other geological parameters. Detailed analytical work was conducted to verify the approach, which is then tested against the real world scenario of the earthquake in the Turkish Region of Marmara. The results provided evidence to prove that the approach is acceptable for producing hazard maps. This is particularly useful for application in developing regions, for emergency response and mitigation purposes, where data is sparse or difficult to collect.

To observe, analyse, monitor, predict hazards and natural disasters, the previous chapters addressed wireless networks, satellite remote sensing, and underwater seismic sensor networks. The Seventh Chapter is a progression from the previous ones, and introduced the use of Unmanned Aerial Vehicles (UAVs), either as individual sources, for collecting information and for emergency communications; or in a universal network architecture to cover large swathes of areas. The UAVs are especially effective in disaster affected regions where the civilian infrastructure may have been demolished, roads blocked by debris etc. UAVs offer quick access to the disaster area and victims. Thus UAVs can be embedded into the entire life-cycle of disaster management.

In a very thorough piece of work, the authors proposed a universal network architecture for a UAV disaster management and studied issue related to the infrastructure-based connectivity between nodes, and associated characteristics, and considered adhoc and cooperative wireless based network. The proposed architectures were implemented on real time test-bed experiments between the two participating ground stations and a UAV, and the link quality for the performance of the network was studied; and network performance analysed in terms of bandwidth consumption, transmission latency and disruption prone networks. The Chapter provided significant pointers towards the Design considerations for a robust UAV based networked architecture.

The Eighth Chapter introduced the use of Radar Sensor Networks in the detection of humans, as in the debris of earthquakes and other disasters. The Chapter focused on the use of Ultra-Wideband (UWB) Radar systems, which are particularly effective in 'through the wall' penetration. Through elegant analysis, simulation and experimental set up, the author puts forward the efficacy of using UWB radars for detecting humans in disaster affected environments. The work identified six characteristics parameters, which are incorporated into fuzzy pattern recognition systems for robust recognition of human forms from the radar returns. The performance of the detection algorithms was analysed and it was shown that the discrimination is clear, though new tools need to be developed.

The Ninth Chapter was concerned with an important facet of natural disasters—that of the wind velocity. It is received wisdom that very high wind velocity is a precursor of disaster. Cyclones, rising flood waters, tsunamis are all accompanied by incipient increase in wind velocities. Extreme high winds are in themselves a danger to human life and cause damage to the environment. Thus accurate measurement of wind velocity is of immense importance. The Authors in this Chapter studied the use of non-invasive techniques for measuring wind velocity, and provided an analysis of the use of time-of-flight measurements to develop tomographic reconstruction of wind velocities.

This Chapter described the fundamentals of the simultaneous multi-channel time-of-flight measurements and their use in the tomographic reconstruction of 2D horizontal wind velocity distribution. The feasibility and effectiveness of the proposed methods were numerically validated in an extensive simulation study, which comprises an iterative process off line to establish the wind velocity fields, and results illustrated good quality reconstruction. The work needs to be extended to the reconstruction of wind velocity fields using real data.

The Tenth Chapter was concerned with resource optimisation when satellites are used in remote sensing of the environment during emergencies and in monitoring natural disasters. Taking the case of the Multi-beam Satellite Communication System, operating in S band, which plays a significant role in the provision of direct-to-user satellite mobile service; the authors developed an effective algorithm that covers joint power and bandwidth allocation in the presence of inter-beam interference, traffic demand, adverse channel conditions, capacity and demand, and environmental delays. This is a significant improvement on conventional algorithms that tend to allocate separately for power or bandwidth allocation. The work was reinforced by detailed simulations, which showed that the performance of the proposed approach is significantly superior in terms of throughput and energy efficiency, as compared to traditional integrated satellite-terrestrial spectrum sharing scheme at different user density; enhancing the integral energy efficiency at the cost of a small part of the throughput. As a follow on it would be good to test the performance with real data.

The Eleventh and final Chapter is devoted to the vexed issue of localisation accuracy of sources especially in an indoor environment. The concern arises when sources need to be identified in areas where remote sensing is not applicable, as within confined spaces and covered regions. The work reported in this Chapter combined analytical developments with an advanced experimental setup to verify theoretical predictions. Using a three antenna architecture, and commodity Wi-Fi devices, the authors were able to illustrate the detection capabilities that reflect sub-meter accuracy, without the need of any specialised hardware, thus opening the way to the use of commodity or off-the-shelf components. The merit of the approach resides in combining the Angle of Arrival (AoA) returns with Received

Signal Strength (RSS) measurements, to devise an algorithm that yields location with sub-meter accuracy, outperforming conventional systems relying only on AoA or RSS measurements. For detection purposes, an optimal threshold was set, based on the distribution of the AoA and Time of Flight, both for Line of Sight and Non-Line of Sight scenarios; the latter being a specially challenging case. The detection rate of 90% for the two scenarios is particularly impressive. Future work on extending the architecture to LTE and to 5G systems would be worthwhile.