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Infrastructure Monitoring with Spaceborne SAR Sensors

Springer

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ISSN 2191-8112 ISSN 2191-8120 (electronic)
SpringerBriefs in Electrical and Computer Engineering
ISSN 2196-4076 ISSN 2196-4084 (electronic)
SpringerBriefs in Signal Processing
ISBN 978-981-10-3216-5 ISBN 978-981-10-3217-2 (eBook)
DOI 10.1007/978-981-10-3217-2

Library of Congress Control Number: 2017931532

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Printed on acid-free paper

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The registered company is Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Foreword

Spaceborne InSAR (synthetic aperture radar interferometry) is an interesting monitoring technique due to several reasons: does not require an active instrument mounted at the test site, is quite robust to weather conditions, is a relatively long-term guaranteed service with quite frequent revisit times and may allow *a posteriori* reconstruction of the measurements history for a given site provided an availability of SAR products and a suitable site configuration. The InSAR technique is widely employed for large-scale monitoring of general subduction movements, resource recovery exploitations (oil, gas and mining), and of urban areas subject to various disturbances (e.g., water pumping, tunneling and general underground construction work).

The accuracy of InSAR measurements is compatible with the monitoring requirements if performed by qualified personnel.

From a practical point of view, it is worth mentioning that the InSAR technique provides only displacements along the line of sight of the satellite, and hence a displacement that is perpendicular on this direction cannot be measured. This fact generates some limitations in the InSAR technique by making its applicability and interpretability of the results dependent on the geographical configuration of the envisaged site.

Moreover, in the case of water dams and other hydraulic structures, there are additional factors that can limit the sensibility or even the applicability of InSAR: vegetation and snow cover, visibility of the site from a given satellite orbit (e.g., a deep valley may be partly or completely shadowed in a SAR image) or other geometric distortion effects, i.e., layover, foreshortening, which depend on the chosen orbit and the geometrical configuration of the site.

For a given acquisition geometry, artificial scattering centers can be created on the site of interest using corner reflectors. These reflectors have to be carefully designed and set out to ensure high reliability, which can lead to significant in situ instrumentation costs.

Finally, the InSAR technique requires a relatively complex signal processing chain (without real-time capability) and there are only few duly qualified InSAR service providers. Besides, a certain number of images acquired from the same satellite constellation are necessary to start an analysis over a given site.

Therefore, the spaceborne InSAR technology should not be seen as a replacement of classical topographic techniques (e.g., leveling, tachometry, GNSS, LIDAR, photogrammetry), but rather as a complementary monitoring method. Compared to in situ sensors, spaceborne SAR monitoring can provide:

- an overall picture of the studied area (a SAR image can cover areas from tens to hundreds of km), which facilitates the analysis of the site along with its surroundings (e.g., the evolution of a landslide placed on the banks of a reservoir during a drainage of the dam or the early detection of possible instable areas that require precise in situ monitoring with classical techniques);
- monitoring of hard-to-reach areas due to security reasons;
- an optimization of the frequency of measurements over all the available monitoring systems, for example, adding regular InSAR monitoring while spacing out topographical monitoring;
- the ability to recreate, *a posteriori*, the history of deformations;
- and finally, an improvement in the behavioral diagnosis of an infrastructure site (status evaluation before, during and after works/events, aid in the understanding of geological phenomena, etc.).

In this book, the authors present a new approach on infrastructure monitoring with InSAR techniques, based on an independent processing chain that provides original technical aspects in comparison with the classical InSAR methodology. Besides, the developed technique offers solutions to some of the previously mentioned issues of typical InSAR processing, since it requires a relatively reduced number of SAR images and easily rejects scattering centers that are affected by layover and cannot be accurately monitored. A full chapter is dedicated to the measurement campaign at the Puylaurent water dam and Chastel landslide from France and presents a detailed comparison between the displacements that can be measured with different types of sensors. The book is concluded with a special section containing recommendations for the reader on performing infrastructure monitoring surveys with spaceborne SAR sensors.

Lyon, France
November 2016

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Acknowledgements

The authors would like to acknowledge the help provided by *Électricité de France,* who made possible the applicative part of the book. Thanks to Mr. Rémy Boudon, Mr. Guy d'Urso, Mr. Alexandre Girard, and Mr. Didier Boldo for their suggestions and advice from a very practical point of view.

Contents

Acronyms

APC	Antenna Phase Center
ASL	Above Sea Level
BPF	Band-Pass Filter
CRLB	Cramér–Rao Lower Bound
D-InSAR	Differential Synthetic Aperture Radar Interferometry
DEM	Digital Elevation Model
ECEF	Earth Centered Earth Fixed
EDF	Électricité de France
EV	Elevation-Velocity
FFT	Fast Fourier Transform
FM	Frequency Modulation
GLRT	Generalized Likelihood Ratio Test
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IFL	Instantaneous Frequency Law
InSAR	Synthetic Aperture Radar Interferometry
LIDAR	Light Detection and Ranging
LOS	Line Of Sight
MAE	Mean Absolute Error
MDV	Mean Displacement Velocity
ML	Maximum-Likelihood
MLC	Multi-Look Complex
MLE	Maximum Likelihood Estimation
PDF	Probability Density Function
PRF	Pulse Repetition Frequency
PS	Permanent Scatterer
PSD	Power Spectral Density
PSI	Permanent Scatterers Interferometry
PSP	Principle of Stationary Phase
RF	Radio Frequency

RVP	Residual Video Phase
SAR	Synthetic Aperture Radar
SCM	Sample Covariance Matrix
SLC	Single-Look Complex
SNR	Signal-to-Noise Ratio
SSC	Single Look Slant-Range Projected Complex
SPECAN	Spectral Analysis azimuth processing
STFT	Short-Time Fourier Transform
TDX	TanDEM-X
TomoSAR	SAR Tomography
TSX	TerraSAR-X