

# An Optimized Algorithm for InSAR Phase Unwrapping Based on Particle Filtering, Matrix Pencil, and Region-Growing Techniques

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**Abstract**—This letter presents a new phase unwrapping algorithm for synthetic aperture radar interferometry which combines a particle filter, a matrix-pencil (MP) local slope estimator, and an optimized region-growing technique. The advantages of the new method rely on the following contributions: The MP estimator provides better resolution to the local slope estimation, the particle filter enables simultaneous unwrapping and filtering without a priori statistics constraints, and the implemented region-growing technique adds diversity of unwrapping paths and ensures an optimum solution. Results introduced in this letter illustrate the main aspects of the new approach.

**Index Terms**—Matrix pencil (MP), particle filter, phase unwrapping (PU), region growing, state space, synthetic aperture radar (SAR) interferometry.

## I. INTRODUCTION

**I**N PREVIOUS works, the authors presented some phase-unwrapping (PU) algorithms based on the use of state-space techniques, such as the grid filter [1] and the particle filter [2]. The skeleton of these algorithms incorporates two main stages that are executed for every pixel. The first one, known as prediction stage, makes use of the previously unwrapped neighbors and the information provided by a local slope estimator to obtain a prediction for the unwrapped phase at a certain pixel. The second stage, known as update stage, incorporates the measurement (interferometric phase) at the pixel. Then, a filter combines prediction and measurement to obtain the optimal solution for that pixel, based on their covariance matrices, thus providing filtering and unwrapping simultaneously.

Regarding the filter, there are several options with different performances and different features from the view point of the state-space approach. For instance, an extended Kalman filter can be employed [3], and it propagates (i.e., maintains for future use for the rest of pixels) only the adopted solution state and the covariance matrix. In case of applying a particle filter [2], the algorithm maintains both the solution state and a selection from the rest of state candidates (also known as particles). This selection is performed by a third stage known as resampling, and only the states whose associated weights are the highest are maintained.

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Finally, a search strategy can be incorporated to add the capability of selecting the best pixel among all the candidates to be unwrapped at each time.

Among all the versions of the algorithm presented so far, the 2PFFPU, which states for the monoseed path following version of the Particle Filter PU (PFFPU), was demonstrated in [2] to be a very robust PU tool. This solution combines a particle filter, a local slope estimator based on the mode of the power spectral density (PSD) [3], and a monoseed path following search strategy [4].

In this letter, an improved PU solution is proposed. This solution also makes use of a particle filter, like the 2PFFPU algorithm, but it incorporates two important differences which improve the overall performance of the approach. First, the local slope estimator based on the mode of the PSD has been replaced by a matrix pencil (MP) based one, since more accurate local phase slope predictions are expected from such a super-resolution approach and smaller estimation windows can be employed. Second, an optimized region-growing strategy is used to drive the PU paths. As described later, the region-growing approach used here is optimum because only the pixel whose cost function is the best among all regions will be unwrapped at every step. The whole resulting method is more robust than previous ones because it can unwrap zones which other PU approaches simply mask or fail to unwrap, as illustrated in this letter with some examples.

This letter is organized as follows. Section II introduces the basics and advantages of using a particle filter for PU. Section III justifies the use of the MP-based local slope estimator. The optimized region-growing technique is presented in Section IV. Then, Section V illustrates the performance of the new method with some examples from both synthetic and real interferograms. Finally, conclusions are drawn in Section VI.

## II. PARTICLE FILTERING

The particle filter was introduced in [2] to simultaneously perform filtering and PU. The Extended Kalman Filter introduced in [3] shares the same objective. However, the particle filter was shown to achieve better results than the Extended Kalman Filter since the latter is limited to Gaussian models, whereas the particle filter (PF) can model any kind of noise distributions. Note that the noise present in real interferograms is a marginal density distribution of the Wishart one.

# A Region Growing Algorithm For Insar Phase Unwrapping

**BM King**



## **A Region Growing Algorithm For Insar Phase Unwrapping:**

Energy Minimization Methods in Computer Vision and Pattern Recognition Mario Figueiredo, Josiane Zerubia, 2001-08-22

This book constitutes the refereed proceedings of the Third International Workshop on Energy Minimization Methods in Computer Vision and Pattern Recognition EMMCVPR 2001 held in Sophia Antipolis France in September 2001 The 42 revised full papers presented were carefully reviewed and selected from 70 submissions The book offers topical sections on probabilistic models and estimation image modeling and synthesis clustering grouping and segmentation optimization and graphs and shapes curves surfaces and templates

*New Trends in Software Methodologies, Tools and Techniques A.* Selamat, H. Fujita, H. Haron, 2014-08-29 Software is the essential enabling means for science and the new economy It helps us to create a more reliable flexible and robust society But software often falls short of our expectations Current methodologies tools and techniques remain expensive and are not yet sufficiently reliable while many promising approaches have proved to be no more than case by case oriented methods This book contains extensively reviewed papers from the thirteenth International Conference on New Trends in software Methodology Tools and Techniques SoMeT\_14 held in Langkawi Malaysia in September 2014 The conference provides an opportunity for scholars from the international research community to discuss and share research experiences of new software methodologies and techniques and the contributions presented here address issues ranging from research practices and techniques and methodologies to proposing and reporting solutions for global world business The emphasis has been on human centric software methodologies end user development techniques and emotional reasoning for an optimally harmonized performance between the design tool and the user Topics covered include the handling of cognitive issues in software development to adapt it to the user s mental state and intelligent software design in software utilizing new aspects on conceptual ontology and semantics reflected on knowledge base system models This book provides an opportunity for the software science community to show where we are today and where the future may take us

Recent Interferometry Applications in Topography and Astronomy Ivan Padron, 2012-03-21 This book provides a current overview of the theoretical and experimental aspects of some interferometry techniques applied to Topography and Astronomy The first two chapters comprise interferometry techniques used for precise measurement of surface topography in engineering applications while chapters three through eight are dedicated to interferometry applications related to Earth s topography The last chapter is an application of interferometry in Astronomy directed specifically to detection of planets outside our solar system Each chapter offers an opportunity to expand the knowledge about interferometry techniques and encourage researchers in development of new interferometry applications

**Susceptibility Weighted Imaging in MRI** E. Mark Haacke, Jürgen R. Reichenbach, 2014-03-25 MRI Susceptibility Weighted Imaging discusses the promising new MRI technique called Susceptibility Weighted Imaging SWI a powerful tool for the diagnosis and treatment of acute stroke allowing earlier detection of acute stroke hemorrhage and easier detection of

microbleeds in acute ischemia The book is edited by the originators of SWI and features contributions from the top leaders in the science Presenting an even balance between technical scientific aspects of the modality and clinical application this book includes over 100 super high quality radiographic images and 100 additional graphics and tables *Earthquakes* Taher Zouaghi,2017-02-01 This book is devoted to diverse aspects of earthquake researches especially to new achievements in seismicity that involves geosciences assessment and mitigation Chapters contain advanced materials of detailed engineering investigations which can help more clearly appreciate predict and manage different earthquake processes Different research themes for diverse areas in the world are developed here highlighting new methods of studies that lead to new results and models which could be helpful for the earthquake risk The presented and developed themes mainly concern wave s characterization and decomposition recent seismic activity assessment mitigation and engineering techniques The book provides the state of the art on recent progress in earthquake engineering and management The obtained results show a scientific progress that has an international scope and consequently should open perspectives to other still unresolved interesting aspects

**Two-Dimensional Phase Unwrapping** Dennis C. Ghiglia,Mark D. Pritt,1998-04-28 A resource like no other the first comprehensive guide to phase unwrapping Phase unwrapping is a mathematical problem solving technique increasingly used in synthetic aperture radar SAR interferometry optical interferometry adaptive optics and medical imaging In Two Dimensional Phase Unwrapping two internationally recognized experts sort through the multitude of ideas and algorithms cluttering current research explain clearly how to solve phase unwrapping problems and provide practicable algorithms that can be applied to problems encountered in diverse disciplines Complete with case studies and examples as well as hundreds of images and figures illustrating the concepts this book features A thorough introduction to the theory of phase unwrapping Eight algorithms that constitute the state of the art in phase unwrapping Detailed description and analysis of each algorithm and its performance in a number of phase unwrapping problems C language software that provides a complete implementation of each algorithm Comparative analysis of the algorithms and techniques for evaluating results A discussion of future trends in phase unwrapping research Foreword by former NASA scientist Dr John C Curlander Two Dimensional Phase Unwrapping skillfully integrates concepts algorithms software and examples into a powerful benchmark against which new ideas and algorithms for phase unwrapping can be tested This unique introduction to a dynamic rapidly evolving field is essential for professionals and graduate students in SAR interferometry optical interferometry adaptive optics and magnetic resonance imaging MRI

Remote Sensing of Soil and Land Surface Processes Assefa Melesse,Omid Rahmati,Khabat Khsoravi,2023-10-31 Remote Sensing of Soil and Land Surface Processes Monitoring Mapping and Modeling couples artificial intelligence and remote sensing for mapping and modeling natural resources thus expanding the applicability of AI and machine learning for soils and landscape studies and providing a hybridized approach that also increases the accuracy of image analysis The book covers topics including digital soil mapping satellite land surface imagery

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## **A Region Growing Algorithm For Insar Phase Unwrapping** Book Review: Unveiling the Magic of Language

In an electronic era where connections and knowledge reign supreme, the enchanting power of language has become more apparent than ever. Its power to stir emotions, provoke thought, and instigate transformation is really remarkable. This extraordinary book, aptly titled "**A Region Growing Algorithm For Insar Phase Unwrapping**," published by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound impact on our existence. Throughout this critique, we will delve in to the book is central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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web feb 8 2023 a holiday notice for students should include the following information to inform students of an upcoming holiday specify the start and end dates of the holiday including the day and date explain the reason for the holiday whether it is a national holiday a school holiday or any other reason

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web apr 14 2021 from date till date the reason behind the same is not feeling well family issues have to travel any other i request you to kindly consider this as a genuine request and sanction requested leave i shall be highly obliged for your kind support

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web dec 27 2019 holiday letter to school writing tips begin by mentioning your ward s name and grade mention reasons for not being able to take him her on holiday for a while mention that not availing a break for a holiday has taken a toll on your child s performance mention that you have planned a holiday to

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web aug 31 2023 1 write a short and direct subject line the first step in writing your email is to draft an effective subject line the idea is to make your reason for writing clear ideally the subject line also states the dates you re requesting example holiday request 6 11 december 2 state your purpose for writing

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web feb 14 2012 dear sir i am james cameron studying in 8 th grade as we are having an important occasion coming on 8 th april 2012 i may not be able attend the school this letter is in reference for requesting you to grant me a leave for two days that is on 8 th april 2012 to 10 th april 2012

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web taking my minor outside by educate can be a bit of a nightmare especially while the teacher is the character who decides determines thou can go on holiday during term times it seems a shred unfairly but the law in the britain means that students can only go on holiday in exceptional circumstances or among one discretion of that school to it

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**letter to school to inform of holiday during term time mumsnet** - Apr 04 2022

web may 20 2007 letter to school to inform of holiday during term time 5 replies sugarybits 20 05 2007 20 50 would someone mind telling me if this is sufficient please re xxx xxxx morning nursery class i am writing to inform you that we will be taking xxx on holiday week commencing monday 4th june for 1 week

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web may 3 2012 here is our preview for taking child out of school to holiday letter if you want a few more from the letter then you can locate 4 more detailed examples here one theme is for follows dear teacher s name i m writing to order permission for my child child s name to be absent of educate from start date to end date due to our famil

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web mar 26 2020 a holiday request letter is a formal document to notify the relevant parties of your absence the number of days taken and the purpose of leaving tips for writing a holiday request letter specify the duration and dates for leaving and resuming work

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web jan 24 2023 paragraph 1 introduce yourself and the purpose of writing this letter paragraph 2 now explain the reason in detail paragraph 3 conclude the letter this section must say what you re expecting or the solution complimentary closing now conclude the letter with complimentary closing like yours sincerely yours faithfully etc

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web oct 7 2020 holiday request letter to school october 7 2020 by rahul panchal being a student of a school a child is regularly sent there to gain the required knowledge he or she would need for future studies in other institutions teachers expect full attendance so that a student can get educated properly without missing any lesson

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