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Glacier monitoring using spaceborne SAR intensity images

Berichte aus der Geoinformatik

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Abstract

In last decade, Synthetic Aperture Radar (SAR) is becoming a popular technology for the monitoring of glaciers in polar region and alpine areas, accounting for its specific advantages of being independent from weather and sunlight conditions. In particular, in the field of glaciology, the spaceborne SAR has been widely applied to measure the velocity of glacier surface movement helping the understanding of glacier dynamics, and detect the glacier facies for analysing the mass balance of glacier. However, for the conventional method of glacier surface motion estimation that based on patch-based correlation techniques, there is always a trade-off between the size of matching template and the preservation of local details occurs. Moreover, the traditional methods for glacier facies detection using single polarimetric SAR data are pixel-based ones depending highly on various SAR backscatter coefficients, which are limited by the insufficient information existing in a resolution cell and have the less consideration on spatial distribution of different land covers. Both these factors mentioned have restrained the performance of glacier monitoring.

In this thesis, methods and strategies for the glacier monitoring task, involving the quantitative estimation of glacier surface motion and the multi-objects classification on and around the glacier surface areas, have been developed and evaluated with different research areas and datasets, separately, with spaceborne SAR intensity images used.

The estimation of glacier surface motion is conducted via the extraction of point like features from the intensity image pair and the robust phase correlation algorithm. Additionally, to increase the robustness, an adaptive refined Lee filter is developed for despeckling SAR images, aiming to achieve a trade-off between the suppression of noise and the preservation of local image textures. On the other hand, a supervised classification method of the glacier surface areas is conducted in order to detect the glacier facies. This method takes advantages of the discrimination ability of sparse representations, based on which a feature extraction technique called supervised neighbourhood embedding is constructed. Alternatively, a gradient method is also developed to update the dictionary and the projection matrix.

The test area including six TerraSAR-X images covered two different glaciers, namely the Taku glacier and Baltoro glacier, representing discriminative glacier characteristics in light of dimensions, surface features, topography etc. are used for assessing the performances of methodologies. In addition, simulated SAR dataset are adopted to evaluate the performance of robust phase correlation algorithm and the proposed adaptive refined Lee filter, in the context of SAR intensity images contaminated by noise.

The analysis and discussion about results of glacier movement and classification, under a variety of tests using both the simulated and real SAR datasets, have confirmed the superiority and feasibility of the proposed methods compared to the existing classical methods and algorithms.

Kurzfassung

Zum Zwecke eines besseren Verständnisses der Gletscherdynamik und Massenbilanz wurde Synthetic Aperture Radar (SAR) in großem Umfang angewendet, um die Bewegungsgeschwindigkeit und Flächen von Gletscheroberflächen zu vermessen. Jedoch tritt bei herkömmlichen verwendeten Methoden für die Schätzung von Gletscheroberflächenbewegungen, vor allem auf Basis von Patch-Korrelationstechniken, immer ein Kompromiss zwischen der Größe der passenden Fenster und die Erhaltung der lokalen Details auf. Darüber hinaus sind die traditionellen Methoden zur Gletschererkennung mit einfach-polarimetrischen SAR-Daten pixel-basiert und hängen in hohem Maße von verschiedenen SAR-Rückstreu-Koeffizienten ab, die durch ungenügende Informationen in einer Auflösungszelle begrenzt sind und weniger Rücksicht auf die räumliche Verteilung der verschiedenen Landabdeckungen nehmen.

In dieser Arbeit wird die Bewegungsschätzung der Gletscheroberfläche über die Extraktion von punktförmigen Merkmalen aus einem SAR-Intensitäts Bildpaar und die Verwendung eines robusten Phasenkorrelations-Algorithmus durchgeführt. Darüber hinaus, um die Robustheit zu erhöhen, wird ein neuartiger adaptiver und verfeinerter Lee-Filter für die Entfernung von Fleckenrauschen entwickelt, die nach Erreichung eine gute Balance zwischen der Unterdrückung von Rauschen und die Erhaltung der lokalen Bildtexturen anstrebt. Auf der anderen Seite wird ein überwachtes Klassifikationsverfahren vorgeschlagen um die Detektion von Gletscherregionen abzuschätzen. Das vorgeschlagene Klassifikationsverfahren nutzt die Vorteile der Unterscheidungsfähigkeit von spärlichen Darstellungen aus, und ist auf Grundlage einer Technik zur Merkmalsextraktion mit Einbettung von Nachbarschaften aufgebaut. Außerdem wird ein Gradientenverfahren entwickelt, um das Wörterbuch und die Projektionsmatrix zu aktualisieren.

Die Analyse und Diskussion über die Ergebnisse der Gletscherbewegung und Klassifikation, unter einer Vielzahl von Tests unter Verwendung von sowohl simulierten als auch realen SAR Datensätzen, haben die Überlegenheit und die Durchführbarkeit der vorgeschlagenen Methoden bestätigt, wenn sie mit den bestehenden klassischen Methoden und Algorithmen verglichen werden.

Contents

Abstract	3
Kurzfassung	5
Contents	7
List of Abbreviations	9
List of Figures	11
List of Tables	13
1 Introduction	15
1.1 Motivation and Objective of the Thesis	15
1.2 Structure of the Thesis	16
2 State of the Art in Glacier Monitoring using SAR images	19
2.1 Glacier Surface Motion Monitoring	19
2.1.1 Offset Tracking Method	20
2.1.2 InSAR Based Method	21
2.1.3 Conclusion from the Literature Review	22
2.2 Despeckling and Denoising	22
2.3 Reviews on Image Matching Techniques for Offset Estimation	23
2.3.1 Spatial Domain Correlation Method	23
2.3.2 Phase Correlation Method	24
2.4 Glacier Surface Area Classification	26
2.5 Sparse Representation for Object Classification	28
2.6 Contribution of this Thesis	29
2.6.1 Glacier Surface Motion Estimation	29
2.6.2 Glacier Areas Classification	29
3 Estimation of Glacier Surface Motion	31
3.1 Preprocessing of SAR Images	31
3.1.1 SAR Images Despeckling and Denoising	32
3.1.2 Elimination of Topographic Information	34
3.2 Dense matching between SAR image pair	35
3.2.1 Co-registration	35
3.2.2 Selection of Point Like Features	35
3.2.3 Robust Phase Correlation	36
3.3 Estimation of Glacier Surface Motion	38
4 Classification of Glacier Surface Area	41
4.1 Data-driven Dictionary Learning	41
4.2 Learning Dictionary for Classification	43
4.2.1 Discriminative Features Extraction	43

4.2.2	Linear Classification	45
4.3	Optimization of DPLC	45
4.4	Details on Implementation	46
5	Experiments	49
5.1	Experimental Dataset	49
5.1.1	TerraSAR-X Images	49
5.1.2	Simulated SAR Dataset	50
5.2	Investigated Areas	52
5.2.1	Taku Glacier in Juneau Icefield	52
5.2.2	Baltoro Glacier in Himalyas	54
5.3	Experiment Design	54
6	Results	57
6.1	Glacier Surface Motion	57
6.1.1	Validation of Algorithm using Simulated SAR Dataset	57
6.1.2	Application using TSX Images	59
6.2	Glacier Surface Classification	67
6.2.1	Dataset in the Taku Glacier	67
6.2.2	Dataset in the Baltoro Glacier	72
7	Discussion	79
7.1	Glacier Surface Motion	79
7.1.1	Simulated SAR Dataset	79
7.1.2	Dataset in the Taku Glacier	79
7.1.3	Dataset in the Baltoro Glacier	82
7.2	Glacier Surface Classification	83
7.2.1	Dataset in the Taku Glacier	83
7.2.2	Dataset in the Baltoro Glacier	84
8	Conclusion and Perspective	87
8.1	Summary and Conclusion	87
8.2	Future Work	88
	Bibliography	89
	Lebenslauf	99
	Acknowledgment	101

List of Abbreviations

Abbreviation	Description	Page
ARLee	adaptive refined Lee	31
BC	backscatter coefficients	26
CoV	coefficient of variation	32
DEM	digital elevation model	21
DFT	discrete fourier transform	38
D-InSAR	differential interferometry SAR	21
DPLC	learning dictionary and projection matrix for linear classification	41
EEC	enhanced ellipsoid corrected	49
ENL	equivalent number of looks	32
EPI	edge preservation index	52
FT	Fourier transform	36
GED	generalized eigenvalue decomposition	45
IFT	inverse fourier transform	24
InSAR	interferometric SAR	20
LDA	Linear Discriminant Analysis	72
LMMSE	linear minimum mean square error	33
LOS	line of sight	31
LSM	Least square matching	24
MAI	multi-aperture InSAR	21
ML	maximum likelihood	20
NCC	normalized cross correlation	20
NCR	natural corner reflector	69
NN	Nearest neighbors	43
PC	phase correlation	16
PEF	peak evaluation formula	25
PLF	point like feature	16
RANSAC	random sample consensus	25
RMSE	root mean square error	52
SAR	Synthetic aperture radar	15
SIFT	scale-invariant feature transform	29
SLC	Single- Look Complex	21
SM	stripmap mode	35
SMPI	suppression and mean preservation index	52
SNE	Supervised Neighborhood Embedding	43
SNR	signal to noise ratio	59
SR	sparse representation	16
SSC	single look slant range complex	49
SVD	singular value decomposition	25
SVM	support vector machines	27
SWIR	shortwave infrared	26
TSX	TerraSAR-X	22
VIS	visible spectrum	26
ZNCC	zero mean normalized cross correlation	23

List of Figures

3.1	Overall workflow for the proposed glacier motion estimation approach.	31
3.2	Filtering process of adaptive refined Lee filter.	32
3.3	Filtering masks.	33
3.4	Gradient operators used in the filter in accordance with some feature-aligned windows in Fig. 3.3.	34
3.5	Sketch of topographical mapping of SAR in ground range geometry [Stilla et al., 2003].	35
3.6	The flowchart of dense matching between SAR image pair.	36
3.7	Fattening effect.	36
3.8	Illustrations for the selection of point like feature.	37
3.9	workflow of the proposed robust phase correlation algorithm.	37
3.10	Relationships between the deviation of range and azimuth and change in elevation.	39
4.1	Workflow of two layers learning sparse representation.	42
5.1	Examples of original TSX SAR intensity images after terrain correction.	50
5.2	Examples of simulated SAR intensity images.	51
5.3	Taku Glacier in Juneau Icefield.	53
5.4	The coverage area of the data used in Taku glacier.	53
5.5	The coverage area of the data used in Baltoro glacier.	54
6.1	The filtering results by different filters.	58
6.2	The corresponding results of the different PC methods.	60
6.3	An example of filtering results of real TSX data using the ARLee filter.	61
6.4	The result of topographic relief.	62
6.5	Selection of the scale factor of 2D sinc-function.	63
6.6	Results of selection of PLF using the optimal 2D sinc-function template.	63
6.7	Results of the dense matching in Taku glacier.	64
6.8	Profiles of the 2D motion map.	66
6.9	2D motion field of the glacier surface in the selected image patches.	67
6.10	3D motion map of Taku glacier with the gray values showing the horizontal and the vertical displacement.	68
6.11	3D velocity field of the glacier surface in the selected image patch.	69
6.12	Results of the dense matching in Baltoro glacier.	70
6.13	2D motion field of the glacier surface in the selected image patches.	70
6.14	The study area around the Taku Glacier located in Alaska (the optical image is acquired in August, 2009, from Landsat-5).	71
6.15	Experimental data sets obtained from the single polarization X-band SAR image.	72
6.16	Original image patches randomly selected from TerraSAR-X imagery and their corresponding sparse codes.	73
6.17	The comparison between the distribution of SAR data from Taku glacier in original domain and in sparse domain.	74
6.18	The learning process of our method.	75
6.19	The study area around the Baltoro Glacier located in Karakorum mountain range (the optical image is acquired in November 24th, 2009, from Landsat-5).	75

6.20	Experimental data sets obtained from the single polarization X-band SAR image.	76
6.21	The comparison between the distribution of SAR data from Baltoro glacier in original domain and in sparse domain.	77
7.1	Refinement of the dense matching outcomes.	81
7.2	Histograms of the aforementioned data sets after been processed into BC values.	84

List of Tables

5.1	TSX data delineation used for experiments.	49
6.1	Comparison of filtering performance.	59
6.2	Confusion matrix of the proposed method.	71
6.3	Confusion matrix of SVM.	72
6.4	Classification Performance of the Proposed methods, LDA + NN, direct LDA + NN, and SVM on SR and original data	73
6.5	Confusion matrix of the proposed method.	76
7.1	Classification Performance based on intensity thresholds using original data.	83