The Optimum Selection of Common Master Image for Series of Differential SAR Processing to Estimate Long and Slow Ground Deformation

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***Abstract**—When series of differential SAR image interferometric processing are used to estimate ground deformation, how to select a common master image is a key point. Obviously, the number of possible InSAR pair combinations would explosively grow along with the number of images getting bigger. In the paper, we propose a method that uses a mathematical model to optimize this procedure. In this model, temporal and spatial baselines between various possible interferometric pairs are integrated together, and some other related factors are discussed, too.**

***Index Terms*—Common master image, synthetic aperture radar (SAR), interferometry.**

I. INTRODUCTION

Differential interferometric synthetic aperture radar (DInSAR) is a technique that uses two or three SAR images including common area for interference to estimate the ground deformation during a particular time. It has good precision and can even detect millimeter level movement, so it has been applied in different areas such as detecting mine subsidence, earthquake and volcano activities, glacier movement, and etc. But if the images have low correlation for the surface of ground changed between the periods images acquisition, the registration and interferometric processing are difficult and will elicit poor conclusion. Furthermore, the atmospheric effect will bring error to the interferometric result, in particular of small and slow deformation compared with atmospheric error.

In recent years, in order to overcome the obstacles, instead of using interferograms derived from a few SAR pairs, a method was developed that is able to process a series of interferometric SAR images to deduce the movement velocity at a large number of characteristic points, which have long-term stable attributes in the all pairs. Additionally, it can be used to combat the atmospheric effects and DEM errors. Another merit is that it can fully make use of the image data preserved even if the spatial baseline is greater than the critical upper limit. Hitherto, many people have studied it thoroughly (such as A. Ferretti, C. Prati, F. Rocca, and etc. who called this "Permanent Scatterers Technique– PS"[1]), and some commercial software products have been developed (such as Atlantis Scientific Inc., Gamma Remote Sensing etc.).

How to select a common master image for interferometric processing of so many SAR images is a key point, obviously, the number of possible InSAR pair combinations is very big. Based on interferometric theory and processing experience, most of researchers brow SAR data catalogue to select suitable interferometric images, and choose one as common master image heuristically by minimize spatial and temporal baseline between all interferometric pairs as small as possible. However, when the number of candidate images is big enough, this procedure would be rather difficult and time-consuming if there isn't a systematic method. So we propose a method that uses a mathematical model to optimize this procedure. In this model, temporal and spatial baseline between various possible interferometric pairs will be integrated together, and then optimum selection of common master image is transformed into a mathematical optimization problem. During modeling, the effect of wavelength of SAR, land cover type of research region is considered, too.

II. THE SIMPLE MODEL

If there are N scenes of images, we can list spatial perpendicular baseline B_{ij} and temporal baseline T_{ij} between image *i* and image *j* in a matrix form as figure 1.

In interferometric processing, correlation in interferometric radar can be degraded by thermal noise, lack of parallelism between the satellite flight tracks, spatial baseline noise, and surficial change[2]. So the spatial baseline and temporal baseline are very important. Large spatial baseline will make the incidence angle different, and cause the change of reflective wave. Long temporal baseline can cause time decorrelation. Thereby, a simple model with the spatial baseline and temporal baseline considered is

* This work was supported by NSFC project 40242020, 863 high technology program 2001AA135100, China.

described as function 1.

ID	1	2	3	4	…	N
1	0	T_{12}	T_{13}	T_{14}	…	T_{1N}
2	B_{21}	0	T_{23}	T_{24}	…	T_{2N}
3	B_{31}	B_{32}	0	T_{34}	…	T_{3N}
4	B_{41}	B_{42}	B_{43}	0	…	…
…	…	…	…	…	0	$T_{(N-1)N}$
N	B_{N1}	B_{N2}	B_{N3}	…	$B_{N(N-1)}$	0

Figure 1. The matrix of baselines. The number *i, j (i, j=1,2…N)* is the index of the images, and the B_{ij} and T_{ij} are spatial perpendicular baseline and temporal baseline respectively. Because the absolute value of B_{ij} is equal to that of B_{ji} so is the T_{ij}, we put them in one matrix.

$$Minimize\{\sum_i g_i(B_{ik},T_{ik})\} \quad (1)$$

The k is the index of the common master, g_i (.) is the objective cost function defined as equation (2), where B_c and T_c are common factors, α and β are exponential factors, C_{ik} is linear coefficient. Mostly the B_c can be given the restrictive spatial perpendicular baseline.

$$g_i(B_{ik},T_{ik}) = C_{ik} * (B_{\perp ik} / B_c)^{\alpha} * (T_{ik} / T_c)^{\beta} \quad (2)$$

According to this function, we can calculate the total cost when a certain image as the master is given, and then can select one which gives the minimal cost as the ultimate choice.

III. RESULTS

We acquired 16 ERS1 SAR images' baseline information by the DESCW software (The DESCW software is developed by Eurimage in collaboration with ESA/ESRIN). The real area of these images are near Beijing, and the detailed information of them are showed as Table I:

TABLE I
The information of the images selected for test

Index	Mission	Date	Orbit
1	E1	19920517	4371
2	E1	19920621	4872
3	E1	19920726	5373
4	E1	19921213	7377
5	E1	19930117	7878
6	E1	19930328	8880
7	E1	19930502	9381
8	E1	19930606	9882
9	E1	19930711	10383
10	E1	19930815	10884
11	E1	19930919	11385
12	E1	19931024	11886
13	E1	19931128	12387
14	E1	19950808	21248
15	E1	19960514	25256
16	E1	19971021	32771

Through the DESCW, we can get the spatial perpendicular baselines and temporal baselines between each pair of them. The baselines are showed in table II by the form of figure 1:

TABLE II
List of baselines between the series of images.
The up-right are temporal baselines (days between the two images) and the left-bottom are spatial perpendicular baselines (meters).

Index	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	35	70	210	245	315	350	385	420	455	490	525	560	1178	1458	1983
2	-155	0	35	175	210	280	315	350	385	420	455	490	525	1143	1423	1948
3	756	911	0	140	175	245	280	315	350	385	420	455	490	1108	1388	1913
4	788	943	32	0	35	105	140	175	210	245	280	315	350	968	1248	1773
5	455	610	-301	-333	0	70	105	140	175	210	245	280	315	933	1213	1738
6	834	989	78	46	379	0	35	70	105	140	175	210	245	863	1143	1668
7	1179	1334	423	391	724	345	0	35	70	105	140	175	210	828	1108	1633
8	-304	-149	-1060	-1092	-759	-1138	-1483	0	35	70	105	140	175	793	1073	1598
9	-482	-327	-1238	-1270	-937	-1316	-1661	-178	0	35	70	105	140	758	1038	1563

10	399	554	-357	-389	-56	-435	-780	703	881	0	35	70	105	723	1003	1528
11	1055	1210	299	267	600	221	-124	1359	1537	656	0	35	70	688	968	1493
12	1192	1347	436	404	737	358	13	1496	1674	793	137	0	35	653	933	1458
13	1229	1384	473	441	774	395	50	1533	1711	830	174	37	0	618	898	1423
14	683	838	-73	-105	228	-151	-496	987	1165	284	-372	-509	-546	0	280	805
15	814	969	58	26	359	-20	-365	1118	1296	415	-241	-378	-415	131	0	525
16	148	303	-608	-640	-307	-686	-1031	452	630	-251	-907	-1044	-1081	-535	-666	0

According to equation (1) and (2), we can calculate the corresponding total cost value (see table III) when select a particular one image as the common master. Here, the value of baseline is transformed into positive number before computation. For convenience, we evaluate C_{ik} with 1, B_c with the restrictive spatial perpendicular baseline of ERS1 as 1074m, T_c with the maximal temporal baseline in TABLE II. The α and β are given different values, and the result are shown in TABLE III.

TABLE III
The total value of each case when select one image of index k as the common master

Cost value	The value of [α , β]					
Index	[1, 1]	[2, 1]	[2, 0.5]	[1, 0.5]	[1, 0]	[2, 0]
1	2.642359967	2.111350415	3.90745226	4.764323492	9.751396648	7.96582417
2	2.959248115	2.690639456	5.012308912	5.310904275	11.19459963	10.60793376
3	1.438848931	0.886391609	1.799229154	2.727264281	6.613594041	4.63240761
4	1.213523986	0.775270558	1.754477103	2.536293883	6.673184358	4.841084687
5	1.158533287	0.544859707	1.380280349	2.559642836	7.038175047	4.059882477
6	1.121716152	0.737394166	1.682141763	2.380116742	6.881750466	5.190827551
7	1.818565817	1.5745785	3.221719002	3.512920236	9.682495345	9.685043295
8	2.024877192	1.857448387	4.399228688	4.403708873	12.8594041	13.77607423
9	2.45087574	2.550031756	5.965487507	5.287800067	15.17970205	18.36821486
10	0.963640197	0.393037785	1.104880621	2.250123314	7.246741155	4.230677535
11	1.692444437	1.366095473	2.806948539	3.319837161	8.527932961	7.689606893
12	2.136079394	1.96553603	3.967628687	4.144743532	9.827746741	9.918946731
13	2.351855765	2.253266556	4.497888779	4.550893748	10.31005587	10.61033346
14	2.799797346	1.829236914	2.777118262	4.272906662	6.613594041	4.262685136
15	3.684703124	2.820450413	3.739896785	4.944892586	6.770018622	5.031552455
16	6.492990231	4.514767662	5.190999026	7.420582125	8.648975791	6.065072008

The corresponding chart is show in figure 2. From the table and chart, we can know that mostly selecting images of index 3, 4, 5, 10, 14 will give small cost value, especially the 10th image, and we highlighted this case in table II and table III.

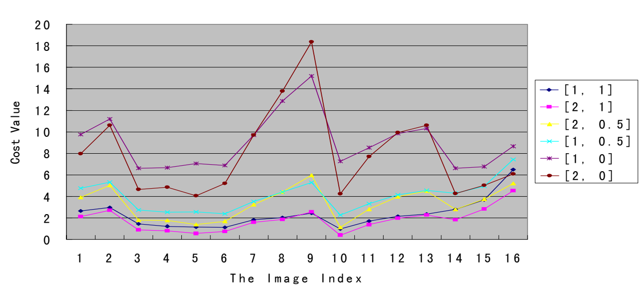

Figure 2. The line diagram of the total cost value of table III.

IV. OTHER CONSIDERATIONS

Except the spatial and temporal baseline, other factors may also be considered. Firstly, the season when the image was got is another important point, because the land cover types and soil humidity are changed greatly in different seasons, and so changed the wave's backscatter quality. So the season, or the month of the date should be considered. Secondly the wavelength is another point to be think over. At last, topography is important, too. The incidence angle will different with variety of the topography, and the baseline will be changed correspondingly. We can alter the parameter C_{ik} to adapt to it.

V. CONCLUSION

From that mentioned above, it indicates that it is easy and quick by the model to select a common master from so many SAR images, and the result is credible to some extent. In further investigation, the model should be improved by taking into account more factors and parameters.

REFERENCE

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