Extraction of Common GCPs from JERS-1 SAR Imagery

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The first step in change detection in any SAR monitoring, including SAR interferometry, is the co-registration of the images. GCPs (Ground Control Points) for co-registration are usually detected manually, but for qualitative analyses of enormous volumes of data, some automation of the process will become necessary. An automated determination of common GCPs for the same path/row data is especially desirable. We selected the intersections of linear features as the candidates of common GCPs. Very bright point targets, which are commonly used as GCPs, have the drawback of appearing and disappearing depending on the conditions of the observation. But in the case of linear features, some detailed elements may appear differently in some case, but the overall line-likeness will remain.

In this study, we selected 18 common GCPs for a single-look JERS-1 SAR image of Omaezaki area in central Japan. Although the GCPs in the first image had to be selected either interactively or semi-automatically, the same GCPs in all other images were successively detected automatically using a tiny sub-image around each GCP and a dilated mask of each linear feature in the first image as the reference data.

1. Introduction

The ability of SAR sensors to be used in all weathers at any time of the day makes them well suited for environmental and disaster monitoring. In order to perform change detection among multiple data sets, the data must first be co-registered. Presently, for each image being compared, this is often done by using cross-correlation methods over small areas, or by manually extracting a large number of tie-points corresponding to the same feature (often point features) and performing affine or higher order transformations. We found that poor control of the orbit of the JERS-1 often caused pixel-level, never mind subpixel-level, offsets that made it difficult to co-register images taken on the same orbital path/row[1].

Note that the co-registration of SAR images requires a different set of considerations than the co-registration of other standard remote sensing images. First, the distance between the satellite antenna and the surface feature directly influences the coordinates of surface features on SAR images reconstructed from observational data. Secondly, the intensity of SAR image pixels (backscattering intensity) are influenced by a number of parameters such as wavelength, polarization, observation angle, incident angle, roughness of the surface feature, its dielectric constant, and surrounding conditions, so that the same feature will not always appear the same[2]. Hence GCPs will often look different depending on the image, or in a worst-case scenario, cannot be seen at all, causing a nearby GCP to be incorrectly identified. These factors make the registration of GCPs in SAR images extremely difficult.

This investigation is on the selection and extraction methods of common GCPs which can be observed at all times on single-look JERS-1 SAR imagery. Although the method used in this investigation was applied to single-look images, it is also general enough to be applied to multi-look images used for monitoring in other fields of study.

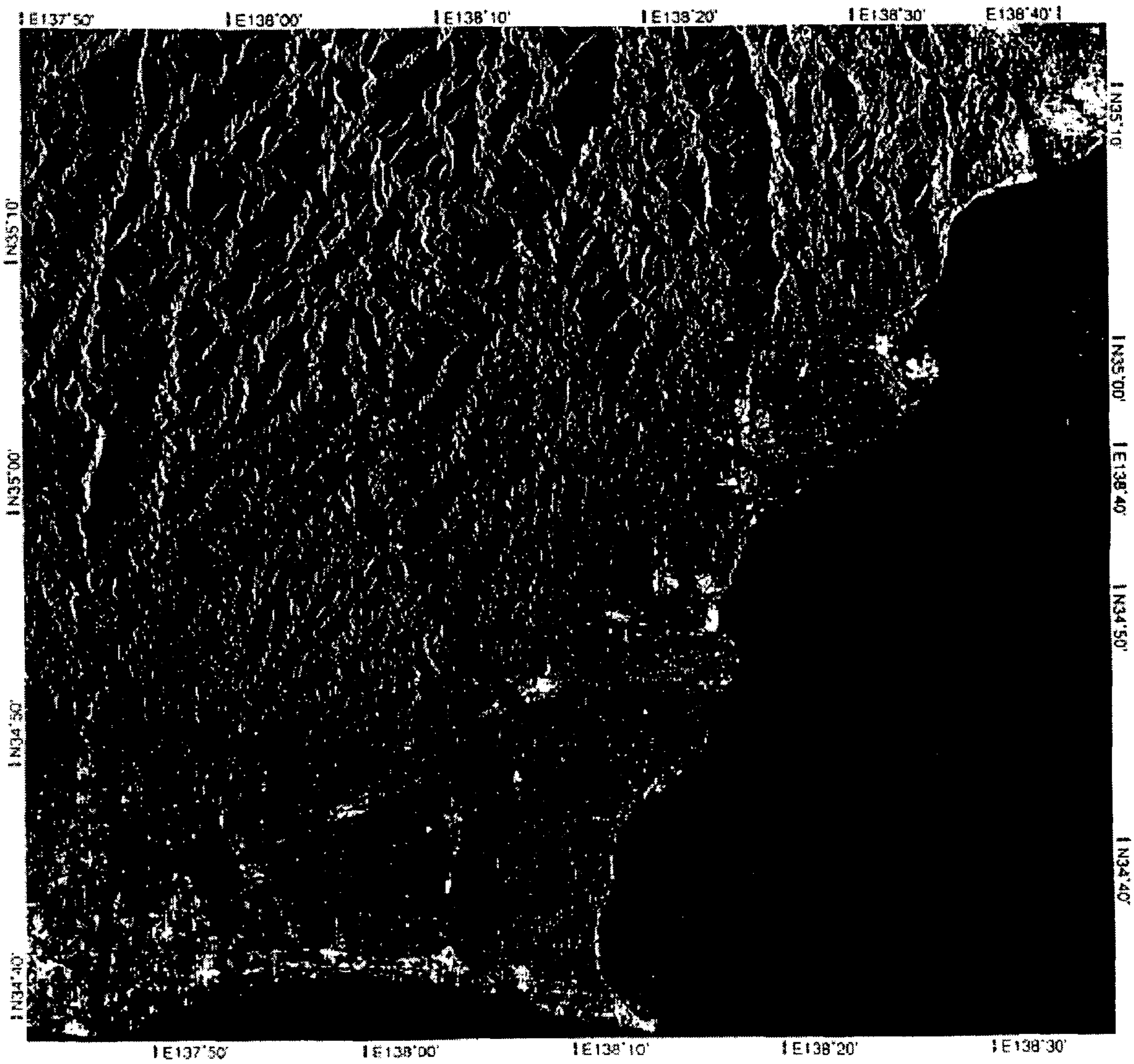

Figure 1. Overall image of the Omaezaki region (after speckle reduction and spatially averaging vertically).

2. Target Area and Data

We at the Earthquake Remote Sensing Project are attempting to quantify subtle crustal movements detected by a method of Differential Interferometric SAR. Our immediate goal is to produce geodetically reliable results through intensive investigations of JERS-1 SAR images of the Omaezaki region, an area with a rich set of other surface measurements (gravity, GPS, and leveling measurements). For that purpose, we plan on installing corner reflectors (CR) as GCPs, and using them to increase the precision of the satellite orbital information, and as tie-points for the registration of images. However, since it would be difficult to distribute a CR network that covers all of Japan, the present investigation was conducted for the sake of extracting other GCPs having characteristics that can be recognized easily in SAR images.

The data used in this investigation are JERS-1 level 0 data (©MITI/NASDA) of the area around Omaezaki for May and October 1996 and January and May 1997. Single-look complex data produced from these data were then transformed onto amplitude images, and speckle was reduced with the SFP [3,4] filter. Because spatial resolution was higher in the azimuthal direction, these images appeared to be stretched by about 2 times towards the azimuth. This made comparison with topographic maps difficult, so the image was halved along the azimuth by taking the mean of two pixels (see figure 1). GCPs were extracted from the resulting images.

3. Features selected for the GCPs

It is difficult to find features within a SAR image that can be compared to geographic features on a map. This is because the intensity of pixels in the SAR image is influenced not only by characteristic speckle noise, but also by other factors.

Table 1. Features extracted as GCP candidates, their location and elevation

GCP number	Approximate map location (longitude, latitude)	Elevation(m)	Feature
1	(138°05'12", 35°02'28")	225	Intersection of two levees
2	(138°19'47", 34°52'23")	5	Intersection of bridge and levee
3	(138°09'11", 34°49'51")	71.1 [1)]	ditto
4	(137°55'35", 34°44'36")	13	ditto
5 [2)]	(138°03'59", 34°39'39")	5.2	ditto
6	(138°04'46", 34°56'00")	143 [1)]	Intersection of railroad and levee
7	(138°09'38", 34°49'27")	67 [1)]	ditto
8	(138°23'15", 34°58'02")	17.2	intersection of two roads
9	(138°17'18", 35°00'08")	80 [1)]	Intersection of road and river
10 [2)]	(138°05'43", 34°44'48")	30 [1)]	ditto
11	(138°17'16", 34°46'41")	5 [1)]	Intersection of road and bridge
12	(138°05'28", 34°59'54")	212	Intersection of dam and levee
13	(138°30'20", 35°01'41")	3 [1)]	Intersection of harbor edges
14 [2)]	(138°12'40", 34°40'53")	5 [1)]	ditto
15	(137°54'52", 34°39'30")	4 [1)]	Intersection of levees
16	(138°16'19", 34°44'55")	2.5 [1)]	ditto
17 [2)]	(138°13'45", 34°37'02")	4 [1)]	ditto
18	(138°05'11", 35°00'08")	205	Power plant

1) The elevation were taken from elevations marked nearby.

2) GCPs 5, 10, 14, and 17 are included in the May and October 1996 images.

Because our goal was to automate the extraction of possible GCP points from SAR images, we had to find features that are easily identified in SAR images at any observation time. Buildings, which appear as bright point features in SAR images, tend to vary in brightness depending on observation time, and become difficult to distinguish, and are hence not necessarily suited as common GCPs. In contrast, linear features such as bridges, railroads, breakwaters, levees, and roads retain an overall structure even when partial details of its composition change in brightness and cannot be seen. It follows that the intersections of such linear features are well suited for use as common GCPs[5,6]. Eighteen GCPs were extracted from the January and May 1997 SAR images. Of these points, 4 were also found within the smaller SAR images from May and October 1996. The results are summarized in Table 1.

4. Extraction Method

Figure 2 illustrates the data flow diagram from preprocessed amplitude images to the final GCP coordinates.

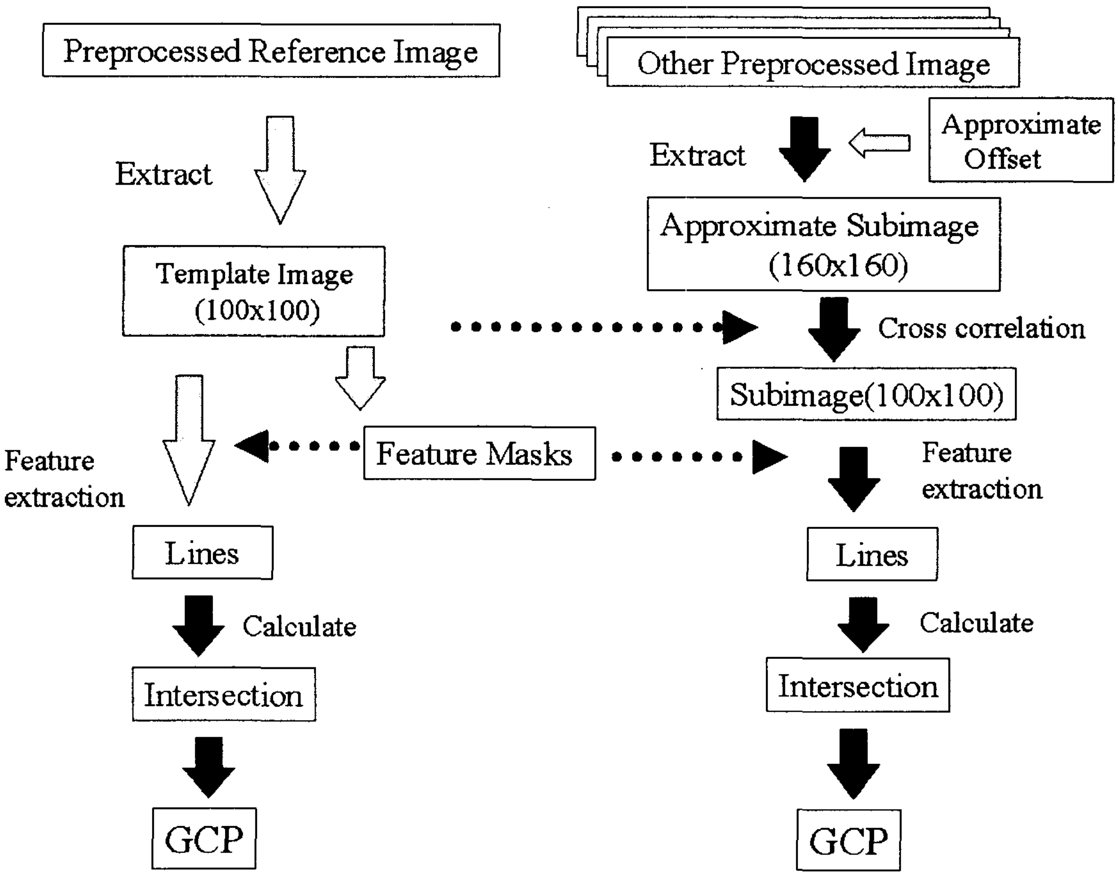

Figure 2. Data flow diagram of GCP extraction. (A black arrow shows an automatic process and a pale gray arrow shows an interactive or partly automatic process.)

Each GCP from the reference image was processed as follows:

1) A small area (100x100 pixels) containing a GCP feature was extracted interactively as a template image from preprocessed data (approximately 6500x8500 pixels).

2) A mask containing a dilated area of targeted linear feature was constructed each component line-like feature of each GCP. (Two masks for each GCP).
3) Straight lines were extracted from inside the feature either interactively or partly automatically.
4) The coordinate of the GCP was calclated as the intersection of two lines.

GCPs corresponding to ones selected from reference image were extracted from the other datasets as follows:
1) Easily identifiable point was chosen and, its offset in the image to the reference image was determined interactively as an approximate common offset of features in the image to the reference image.
2) Using the offset, a small region (160x160) containing each GCP feature was cut out.
3) The cross-correlation matrix of each 160x160 region and corresponding template image(100x100) was calculated and cut out a 100x100 region from the 160x160 region at maximum value.
4) GCPs were extracted automatically using the same method and the same parameters used to extract the corresponding GCPs in the reference image.

5. Results and Discussion

Taking the direction of linear features within the target area into consideration, we selected over 50 candidates for GCPs from a 1:25000 map. These were then compared with the SAR image. However, many could not be used as common GCPs because they could not be seen altogether, because their geographic features looked different depending on observation time, or because they would appear as good GCPs in one time frame but could not be seen in another. It is therefore probable that all extractable common GCP points for JERS-1 within the target area were extracted for this investigation. The number of GCPs can be further increased with the use of bright point targets. We can usually identify the corresponding source of the bright points on the map, but it is often difficult to determine exactly what part of the target caused the reflection, even with an on-site investigation. This is because corner-reflection does not necessarily occur from meaningful targets, but from corners which happened to form a suitable angle for strong reflection in relation to the radar; strong signals from what appears to be the same location do not necessarily represent reflections from the exact same corner. The number of GCPs can be increased if a detailed on-site examination determines exactly where the reflection came from.

The extracted GCPs were located very accurately, usually within one pixel. However, a small number of GCPs were offset by 3 to 7 pixels. In all cases, these were believed to be temporal variations in pixel values influenced by satellite observation parameters and surrounding ground conditions at the time of observation.

The comparative offsets of the GCPs in all 4 images, using GCP(14) as a fixed point, are shown in figure 3. The arrows in the figures indicate the direction of the offsets, with the length of the arrows representing the magnitude (x30) of the offset.

6. Conclusion

In this investigation, the intersections of stationary linear features were used to as GCPs. This method was used to extract common GCPs from 4 SAR images of the Omaezaki area taken at different times along the same orbital path/row. For the first image used for reference, the location of the GCPs had to be determined semi-automatically, but for the other images, the extraction was fully automatic. We plan on using these GCPs as common GCPs for multiple JERS-1 images over this region taken over other observation times. Future research will be conducted on how the results of this investigation will influence comparisons of the satellite's orbit path and location.

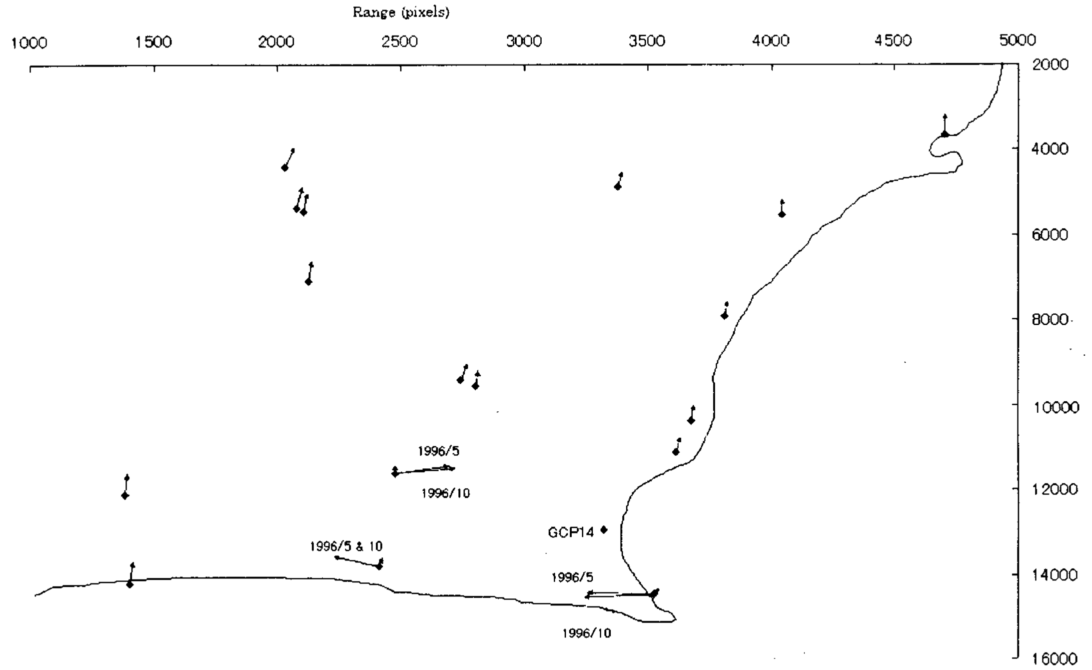

Figure 3. Offsets of the GCPs in three images (from May 1996, October 1996, and May 1997) compared to the GCPs in the January 1997 image. (Fixed point = GCP(14), magnitude of offset multiplied by 30). Arrows with observation date not indicated represent offsets for the May 1997 GCPs.

7. References

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