Image Registration Issues for Change Detection Studies

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Abstract

Change detection studies require that all spatial information be registered to a common coordinate frame. A previous image-to-map rectification study was performed by registering pixel locations to map positions in a local coordinate frame for all images in the time series. However, the precision of this study was unable to be quantified due to the uncertainty of the map generalisation (Israel et al. 1996). A better technique is to register a single image to the coordinate frame either by using conventional survey techniques, such as GPS, or by having known camera position and orientation parameters (internal and external control). The geocoded image becomes the base map. The other images are then registered to the image base map. In this case study, we have used the North Basin of the Dead Sea as our study area. We compared our results to those found by multiple image-to-map registrations.

Introduction

Monitoring large-area temporal changes, whether human induced or naturally occurring, requires a sufficient amount of archived imagery to note the changes. Ground reference information must be available to determine the local datum for quantifying the changes that are observed. Large area monitoring is neither cheap nor easy but is required for planning and management of natural resources (Estes and Mooneyhan 1994).

Israel is exploiting the mineral resources available within the Dead Sea. To do this they are effectively draining the North Basin in evaporation ponds to the south. Israel et al. (1996) attempted to assess the changes in the sea level using manned space photography registered to a 1:250,000 scale map (REF _Ref385752423 * MERGEFORMAT Figure 1). The precision of this analysis was unable to be determined due to the uncertainty of the map generalisation. This analysis repeats the process using a geometrically corrected and georeferenced Landsat Thematic Mapper (TM) image as the registration map and to quantify mapping precision.

This project demonstrates a low cost computer processing methodology to monitor large area changes. The manned space photography is publicly available at low cost. The image area has a similar ground footprint to a SPOT scene for high spatial resolution photographs (Israel 1992). However in New Zealand, an unregistered SPOT image costs approximately three hundred times that of unregistered manned space photography. We will show that using image-to-image registration of imagery is not only less expensive but faster and more accurate than image-to-map registration for change detection issues.

Procedures

Manned space photographs of the Dead Sea have been

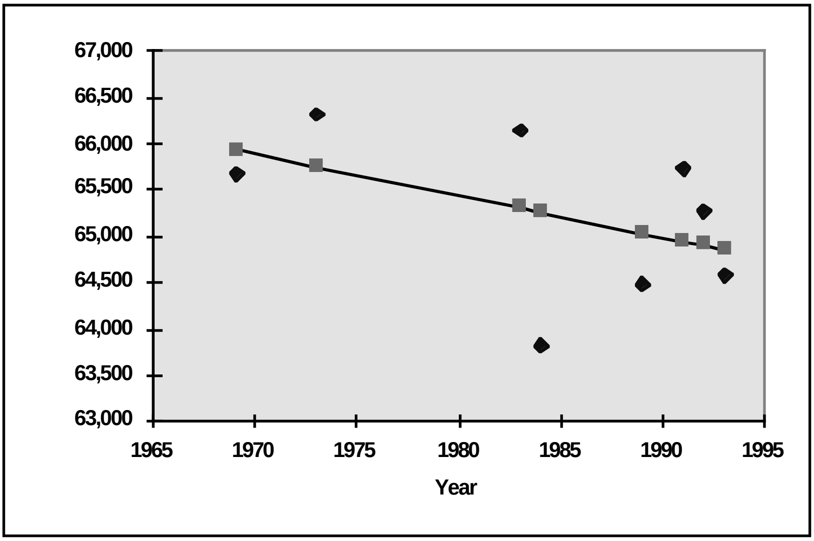

Figure 1 Decline of Dead Sea Surface Area by Year - taken from (Israel et al. 1996)
Note: ♦ indicates raw data values; and ¶ indicates linear regression line.

analysed from Apollo 9 in 1969 through to the Space Shuttle mission STS-47 September 1992. Publicly available 35 mm slides were taken from the original 70 mm format slides and tested for their suitability for analysis. Criteria for suitability were a small zenith angle of photography, a high target-to-background contrast, and a complete photographic coverage of the site and surrounding area to perform image registration (Duggin, 1990 #10).

The slides were all scanned at 600 dots per inch (dpi) and transferred to ERDAS/Imagine image analysis software for processing. 600 dpi is the highest resolution of the scanner. If the image data needed to be stored for long periods of time, then scanning resolution would have been optimised. The scanned image data was then visually inspected for usability based upon the above criteria.

Image Registration

The registration process was performed using a 1984 TM image with the standard geometric corrections (Lillesand and Kiefer 1994), as provided by United States Geological Survey (USGS). The red band of the 1984 TM image was used as it contained significant contrast between the Dead Sea and the surrounding coast and readily observable land marks for registration. The corresponding features on each manned space photographic image were registered to the TM image. Only manned space images that registered with a root mean square (RMS) error of less than 1 pixel were accepted for analysis. As each digitised manned space photograph is of different scale, the area contained by one pixel will also vary. This ground resolved cell (GRC) is a function of the acquisition parameters, film format and orbital position and orientation relative to the target area. Although the GRCs of each image pixel will vary due to the acquisition geometry, after the rectification process all image pixels contained the same linear cross section of ground projection. All rectified manned space photography images were overlaid on the TM image to visually inspect the precision of the rectification. It was found in some cases that even though the RMS error was below 1 pixel there were still obvious flaws in the rectified image. These flaws were corrected by increasing the number of registration points, especially in areas where the difference between the TM image and the manned space imagery was obvious. The image transformation was performed using the standard nearest neighbour algorithm for rectification (ERDAS 1994).

Image Analysis

Each rectified image was then analysed to establish the area of the Dead Seaís North Basin in pixels. The area of each pixel in metres is known and hence the area of the North Basin on each manned space image can be calculated. Thus, the relative volume of water lost from the North Basin may be inferred.

Establishing Area-of-Interest

A single pixel was identified within the North Basin. Then, a worming function was performed to compare the digital value of the target pixel with its neighbours. The comparison is the spectral Euclidean distance. The worming function produces a vector area of interest (AOI) containing all adjacent pixels. As this is an accumulative function, each new pixel has the same function applied to its neighbouring pixels for the same range. The process continues until all pixels that are within the range, and are in contact with each other are identified. The AOI is then visually compared to the area of the North Basin. The process is repeated with different spectral distances to ensure the entire North Basin and only the North Basin is identified as one AOI. In some cases, it was not possible to identify the entire North Basin using a single AOI. In these cases, multiple AOI were identified with varying spectral Euclidean distances. These individual sub-AOIs were then merged.

Pixel Counting

The final AOI was then assessed by counting the total number of pixels and hence the total area of the North Basin. The counting procedure was repeated for an AOI with higher and lower spectral Euclidean distances.

Error Assessment of Area

The major components of error are identified. The maximum possible error due to registration is the RMS error multiplied by the total length of the major axis. In this case, the major (North-South) axis of the North Basin is multiplied by the RMS rounded to the equivalent of 1 pixelís GRC.

To determine the accuracy of the AOI identification some of the images were reassessed at slightly higher and lower spectral distances. This enabled us to calculate the percentage difference in total area caused by slight variations in the spectral distance. The appropriate selection of the distance defining the AOI is subjective. Recreating the AOIs

Year	Month	Image	GRC metres	Total Area pixels	Total Area hectares
1969	March	AST9 562	778	1099	66521
1982	November	STS 57-75	405	4119	67562
1983	November	S09 50 1362	343	5603	65919
1984	October	41G 120 056	687	1345	63480
1985	October	S51J 50 084	217	13371	62963
1989	October	S34 84 067	368	4800	65004
1991	April	S37 151 124	348	5401	65408
1991	June	S40 612 245	384	4393	64777
1991	June	S40 606 015	466	2835	61564
1992	March	S45 95 88	595	1766	62521
1992	September	S47 82 60	249	10474	64940

Figure 2 Results of Analysis
The results show an irregular decline in the size of the North Basin. The decline is not a linear function due to varying seasonal conditions, increases in water use, and errors in acquisition and processing. There are two areas of the analysis which can be affected by errors. The rectification processís susceptibility to errors has been minimised through using rectified images with an RMS error of less than one pixel.

Year	Month	Image	GRC	Total Area	Total Area	Max. Error Registration	Percentage Difference
			metres	pixels	hectares	hectares	
1969	March	AST9_562	778	1099	66521	4046	6
1982	November	STS 057_75	405	4119	67562	2106	3
1983	November	S09_50_1362	343	5603	65919	1784	3
1984	October	41G_120_056	687	1345	63480	3572	6
1985	October	S51J_50_084	217	13371	62963	1128	2
1989	October	S34_84_067	368	4800	65004	1914	3
1991	April	S37_151_124	348	5401	65408	1810	3
1991	June	S40_612_245	384	4393	64777	1997	3
1991	June	S40_606_015	466	2835	61564	2423	4
1992	March	S45_95_88	595	1766	62521	3094	5
1992	September	S47_82_60	249	10474	64940	1295	2

Figure 3 Registration Error Assessment

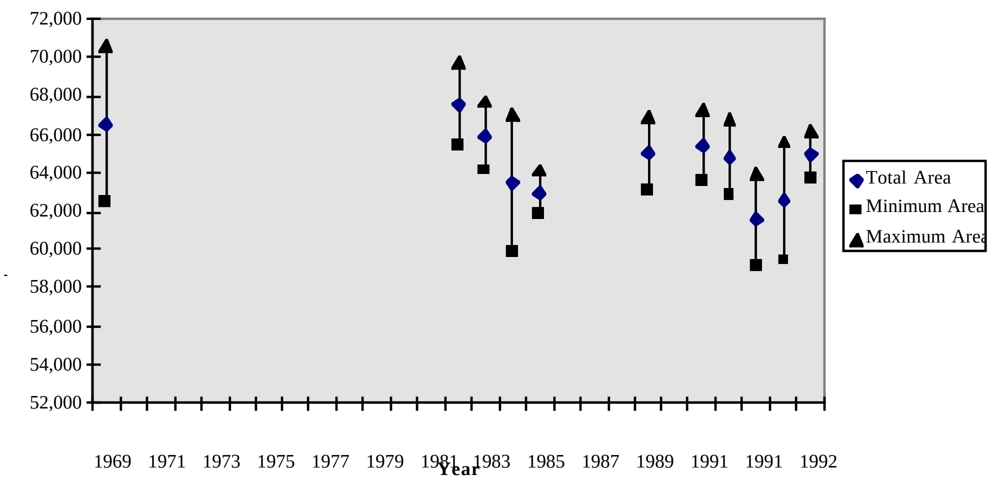

Figure 4 Rectification Error Assessment.

with higher and lower spectral differences gave us an indication of relative error due to operator subjectivity.

Results

A total of twelve images (including the TM image) were analysed. The image acquisition dates range from March 1969 through to September 1992. The results of analysis are shown in REF _Ref385749349 * MERGEFORMAT Figure 2. Relating these results to those found in REF _Ref385752423 * MERGEFORMAT Figure 1 shows little difference in the change in the area over time.

Registration Error

This means that the maximum possible error due to registration is the area of one pixel multiplied by the length (as this is larger than the width) of the North Basin (REF _Ref385751427 * MERGEFORMAT Figure 3). Given that the area we have identified as that of the North Basin (REF _Ref385749349 * MERGEFORMAT Figure 2), is correct, then the variation due to rectification error is simply that area, plus or minus the area of one pixel multiplied by the length of the North Basin (REF _Ref385749364 * MERGEFORMAT Figure 4).

Year	Month	Image	Spectral Distance	Rows	Columns	Pixel Size	Total Area	Total Area	Difference area
			digital number	pixels	pixels	metres	pixels	hectares	percentage
1969	March	AST9_562	34	900	601	778	1099	66521	
1969	March	AST9_562	29	900	601	778	1082	65492	2
1969	March	AST9_562	39	900	601	778	1119	67731	2
1984	5th August	TM of North Basin	20	3094	2045	28.5	829006	67336	
1984	5th August	TM of North Basin	15	3094	2045	28.5	824092	66937	1
1984	5th August	TM of North Basin	25	3094	2045	28.5	839204	68164	1
1984	October	41G_120_056	20	286	297	687	1345	63480	
1984	October	41G_120_056	15	286	297	687	1345	63480	0
1984	October	41G_120_056	25	286	297	687	1345	63480	0
1985	October	S51J_50_084	50	536	347	217	13371	62963	
1985	October	S51J_50_084	45	536	347	217	13156	61950	2
1985	October	S51J_50_084	55	536	347	217	13526	63693	1
1992	March	S45_95_88	31	307	312	595	1766	62521	
1992	March	S45_95_88	26	307	312	595	1727	61140	2
1992	March	S45_95_88	36	307	312	595	1814	64220	3
1992	September	S47_82_60	Composite	554	453	249	10474	64940	
1992	September	S47_82_60	15	554	453	249	8364	51858	20
1992	September	S47_82_60	20	554	453	249	11806	73198	13

Figure 5 AOI Error Assessment

Area-of- Interest Selection Error

As discussed earlier, the process of identifying the appropriate AOI is subjective. Once the appropriate AOI was selected the spectral distance was noted. The analysis was then repeated using spectral distances five greater and less than the original value which corresponded to + 15%. Five images were resampled to illustrate the relative errors. The results of this resampling are shown in REF _Ref385749380 * MERGEFORMAT Figure 5. The images with merged AOI are subject to the possibility of larger errors. AOI error assessment shows the percentage variation in area for each image as it is resampled with different spectral distances.

Discussion

This research quantifies the error sources associated with multidate image merging. Because the control of the registration procedure was much better than the previous attempt by Israel et al. (1996) the possibility of large errors in the image-to-map registration process was minimised (REF _Ref385749364 * MERGEFORMAT Figure 4) and consequently the error analysis was focused on the actual image analysis procedure. We also found a difficulty in pixel counting for our AOI in ERDAS/Imagine due to its approximation of pixels in an area. Consequently, we found it necessary to develop our own pixel counting software.

Our confidence in the accuracy of the data can be seen in the percentage error estimates for the samples of the data. The images with merged AOI show obvious areas of large error. This error has been somewhat exaggerated due to the error assessment being done with regards to one AOI inside the obvious boarders of the North Basin and one which is minimally outside the boarders. It was expected that images with larger GRCs would consequently show greater variability in the accuracy of total area analysis. This was not the case. It appears that the main cause of error in images is the lack of image contrast in some images between land areas and the water of the North Basin.

Conclusion

The procedures developed here may be applied to a wide range of change detection problems. Manned space photography is a low cost alternative to environmental satellite image data, and the database spans over 30 years. However, additional costs include increased registration and computer processing time. We have shown that the cost and the processing time for these analyses can be minimised.

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