Mapping from Fused High Resolution Satellites Stereo Imageries

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Key words: Mapping, IKONOS imagery, SPOT images, Image Fusion, etc.

SUMMARY

With the availability of multisensor, multitemporal, and multiresolution image data from operational Earth observation satellites, the fusion of digital image data, became a valuable tool in remote sensing image evaluation. Fused images provide increased interpretation capabilities and more reliable results, since data from different characteristics, are combined. Therefore, the aim of image fusion is to integrate complementary data, in order to obtain more information, than can be derived from single-sensor data alone.

Consequently, the main objective of this paper is to assess the accuracy of maps, produced by image fusion technique from high resolution single optical IKONOS image, and stereo SPOT-P imageries. To achieve such an objective, eighteen sharp and well distributed check points are chosen on both the reference (aerial orthophoto map, covering the El-Moqatum Plateau, Naser City, Cairo, Egypt) and the resulted geo-corrected and geo-coded images (IKONOS + Left and IKONOS + Right fused images) for the same region. Ten points from them ware measured on the flat terrain and the other (8 points) are measured on the top of buildings. Then, their coordinates ware measured and transformed using well defined and good distributed common points over the same area. Finally, discrepancies of coordinates of those points are evaluated. The Root Mean Square (RMS) error of positional discrepancy, in easting and northing directions, is computed. The results showed that, geo-corrected single IKONOS images, as well as the geo-coded fused images (single IKONOS and SPOT-P), corrected using GCPs derived from orthophoto maps of scale 1:10,000, is acceptable by the American National Map Accuracy Standard (NMAS) specifications in production and updating of maps with scale 1:20,000 (practical mapping scale of 25,000) or less, in case of flat terrain, and the geometric accuracy of the top of buildings is worst than that of the points on the flat terrain, which is true due absence of DEM. Regarding the qualitative assessment, there is an increasing description or detectability for the different land use features, in the new fused images compared to the original single images alone, which helps strongly in photo interpretation results.

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1. INTRODUCTION

1.1 General

It is known that, any national development, either on the local and/or regional levels, depends mainly on the geometrical relationships between all existing natural features (e.g. mountains, hills, rivers, deserts, forests…..etc) and artificial features (e.g. roads, railways, bridges, tunnels, buildings…etc) on the actual surface of the Earth, within the area of interest. The simplest way of presenting such relations, with appropriate dimensions and reasonable scale, is known to be a map sheet. Such map was previously produced as a hard copy map sheet, however, the production is recently performed as a digital soft copy map. Such a map should essentially exist, with the reasonable drawing scale, for planning, setting out, execution, and management of any engineering project [**Wolf and Dewitt, 2000**].

One of the major problems in developing countries, like Egypt, is the lack of up-to-date large scale maps, containing the basic information for many applications in the fields of: engineering surveys, earth resources survey, water management, urban growth, and agriculture. Such required large-scale maps could be in the form of production, revision, and/or updating, of course, under some adopted controlling map accuracy standards.

Nowadays, there is useful information, provided by remote sensing satellites, in the form of single and overlapped images, which can be used for the underlined purpose of large-scale mapping **[Diefallah, 1989]**. This depends on the number and type of cameras mounted on the board of these remote sensing satellites. Consequently, the application of remote sensing data could be an alternative method of supplying information relevant to topographic map production, revision, and updating, which is repetitive, cost-effective and relatively fast operational monitoring system **[Pohl, 1996]**. However, such remote sensing techniques require regular temporal data acquisition. In fact, the use of fused remotely sensed data, from IKONOS and SPOT-P imagery systems, for large-scale map production in Egypt, will represent the backbone of the present investigation.

1.2 Motivations Behind the Present Research

The activity explores the idea of combining images, taken from different imagery systems, using digital image fusion techniques to produce and update large-scale maps. Such combination of different remotely sensed data, are sought to be used for producing and/or updating large-scale maps in Egypt. Hopefully, the results will be useful, for many remotely sensed data users, such as: photogrammetrists, urban planners, soil scientists, water resources managers and many other users, particularly from the economic and time points of view.

1.3 Objective of the Research Work

Studying the usage of image fusion techniques by combining different satellite images, such as IKONOS and stereo SPOT-P in this case, to produce large scale maps to be used for different applications in 3-D mode. Then, this activity could be expanded to be a complete project using new data types, which can be serving in building GIS layers.

1.4 Scope of Presentation of Research Material

In this research project, which is carried out at National Authority for Remote Sensing and Space Sciences (NARSS), located in Cairo, Egypt, a description of the available data used in the practical work is stated. After that, the methodology, as well as the assessment, the conclusions and recommendation are presented. Finally, a list of mentioned references during the report is provided.

2. DATA ACQUISITION

2.1 Space Imageries

Due to the limitations in the newest images at NARSS, specially the stereo ones, the research is carried out using the available data in NARSS's archive. These sets of data are:

- Raw single IKONOS imagery, a fragment of raw imagery over Cairo, Egypt, taken at 1999. The image is corresponds to a topographic map of scale 1:100,000 (sheet No. NH 36 I3), for Cairo region and the approximate geographic coordinates, for this image are as follows [**Space Imaging, 2005**]:

Point	φ	λ
Lower Left corner	30° 00’ 00”	31° 12’ 00”
Upper Right corner	30° 08’ 30”	31° 21’ 00”

- Raw stereo SPOT imageries, a fragment of raw imageries (resolution of 10 m) over Cairo, Egypt. The left one was taken at 5/7/1995, while the right image was taken at 25/7/1995. The processing level for both of them is 1A **[CNES, 2005]**.

2.2 Orthophoto Map

Unfortunately, due to unavailability of ground control points captured by ground surveying, the control used in the research, either as Ground Control Points (GCPs) or the check points, is based on an old orthophoto map produced by the aerial photogrammetric means for a small region (El-Moqatum Plateau) of scale 1:10,000. Accordingly, the project area in this research is limited to the area of aerial orthophoto map available.

3. METHODOLOGY OF THE PRACTICAL WORK

Firstly, the common area (for El-Moqatum Plateau), for which the GCPs are available, between both the raw IKONOS imagery and the raw stereo SPOT imagery is determined, so the control of the research can be done. Consequently, the determined area is cut from all the available images, as shown in Figures (1), (2) and (3).

The software used in the research is ERDAS Imagine **[ERDAS, 2001]**. Through this software and its modules, the fragments of all cut imageries: IKONOS, left and right SPOT imageries are geometrically corrected and georeferenced using the same ground control points, which are derived from the orthophoto map, mentioned before. The location and distribution of these GCPs over the raw IKONOS imagery is displayed in Figure (4). Table (1) shows the residuals and Root Mean Square Error (RMS) for these GCPs.

The next step is the geo-coding the images to create the new fused images (Left SPOT with single IKONOS) and (Right SPOT with single IKONOS). The new fused images are shown in Figures (5) and (6).

4. ASSESSMENT OF RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Assessment of results follows different steps:

- Calculation of statistics from the check points derived from the geo-corrected single IKONOS image, as well as the fused images, to assess the accuracy of maps that could be produced from this kind of images, taking into consideration the accuracy of capturing GCPs from orthophoto map. The procedure in this step is based on 2-D Affine transformation for the check points using the parameters calculated through the GCPs previously used for the correction of images;

- A complete map production from the fused image; and
- Qualitative and quantitative assessment of the 3-D stereo viewing from the fused images.
- The results of the first step can be outlined as follows:

Eighteen sharp and well distributed check points are chosen on both the reference (aerial orthophoto map) and the resulted geo-corrected and geo-coded images (IKONOS, Left and Right fused images). Ten points from them ware measured on the flat terrain and the other (8 points) are measured on the top of buildings. Then, their coordinates ware measured and transformed using well defined and good distributed common points over the required area. Finally, discrepancies of those points are calculated. Tables (2) and (3) show the E, N discrepancies for 10 and 8 points measured on flat terrain and on the top of some buildings, calculated from the geo-corrected single IKONOS image. Also, Tables (4) to (7) show the same but for geo-coded right and left fused images, respectively.

- The results of the second step, which is a complete map production from these images, and due the fact that the RMS of discrepancies of coordinates, either for flat terrain or for the top of buildings, is almost the same for both left and right fused images, the topographic map is produced from the fused image between the left SPOT and IKONOS. Figure (7) show this topographic map.

- For the third item of assessment, which is the qualitative and quantitative assessment of the 3-D stereo viewing from the fused images, the Photoshop program is used to give every fused image a separate color (red – green) to give the stereo model an anaglyphic viewing effect. Then, the common features in both images are overlaid (Figure 8), and consequently a complete check for qualitative viewing for the stereo model has been done using a simple anaglyphic paper glasses [Yun Zhang,2002]. The check is done by experts in both fields, namely: photogrammetry and geology. Figures (9) to (11) show the stereo effect for the critical features (i.e. hills, buildings, green areas, …..etc) appeared in the stereo fused images, against the same ones appeared in the single IKONOS imagery, as well as the complete stereo model itself.

- For the quantitative measurements from the 3-D stereo model, to derive the heights of features, and hence calculate the DEM, unfortunately, the overlap between the two SPOT images are very big, in addition the common cut area, for which the GCPs are available, is located in a small portion in the stereo model. Consequently, this step couldn't be completed through this report.

Regarding the assessment of obtained results, the following conclusions can be outlined:

- Regarding the geometry of the different images, and based on the adopted Map Standards Accuracy NMAS **[Anderson and Mikhail, 1998]**, for geometric accuracy with confidence region 90%, and from the results showed in Tables (2) to (7), it can be stated that the accuracy of mapping from geo-corrected single IKONOS images, as well as the geo-coded fused images (single IKONOS and SPOT-P), corrected using GCPs derived from orthophoto maps of scale 1:10,000, gives an RMS value of 10.42 m in planimetry, which satisfies theoretical large scale mapping of 1:20,000 and smaller (practical mapping scale of 25,000), for flat terrain.

- The geometric accuracy of the top of buildings is worst than that of the points on the flat terrain, which is true due absence of DEM.

- Regarding the qualitative assessment, and from Figures (9) to (11), it is obvious that there is an increasing description or detectability for the different land use features, in the new fused images compared to the original single images alone, which helps strongly in photo interpretation results. For example, the appearance of buildings in land use category, gained more sharpness and has a shadow effect. The same results are true for the drainage patterns and green areas, within the desert category. Also, the majority of land use items become more clearly defined.

Some recommendations for this research can be outlined as follows:

- Completing the project using GCPs captured from ground surveying.
- Calculating the DEM from the whole stereo model of SPOT using ground surveying GCPs.
- The same for the above item but for the fused images.

Table (1)

Residuals (meters) of the Ground Coordinates for the 7 Control Points After Least Squares Adjustment, IKONOS Corrected Image.

No.	Point ID	Residual E	Residual N
1	2	**0.433**	**0.365**
2	6	**-0.012**	**0.082**
3	9	**0.655**	**-0.760**
4	10	**-1.206**	**0.024**
5	12	**-0.013**	**-0.148**
6	15	**0.264**	**0.374**
7	16	**-0.121**	**0.061**
AVMR*		**1.206**	**0.760**
RMS		**0.555**	**0.356**
RMS_p		**0.659**	

* AVMR = Absolute Value of Max. Error.

Table (2) & (3)

E, N Discrepancies for 10 Points on Flat Terrain & 8 Points on Top of Buildings (meters), Single IKONOS Geo-corrected Image.

No.	Point ID	Δ E	Δ N	No.	Point ID	Δ E	Δ N
1	1	0.28	-1.37	1	5	-5.39	-7.71
2	2	-0.003	-2.32	2	6	-4.88	-11.99
3	3	1.27	1.43	3	7	-8.14	-18.53
4	4	-0.56	0.21	4	9	14.82	10.09
5	8	-3.44	-4.81	5	10	15.87	10.94
6	11	1.38	1.57	6	12	-4.99	-10.48
7	14	-4.39	-9.26	7	13	-7.00	-11.95
8	15	4.07	4.77	8	17	8.90	20.05
9	16	-1.78	-5.71				
10	18	0.74	2.41				
AVMR*		4.39	9.26			15.87	20.05
RMS		2.35	4.27			9.64	13.34
RMS_p		4.87				16.46	

* AVMR = Absolute Value of Max. Error.

Tables (4) & (5)

E, N Discrepancies for 10 Points on Flat Terrain & 8 Points on Top of Buildings
(meters), Right Fused Image.

No.	Point ID	Δ E	Δ N	No.	Point ID	Δ E	Δ N
1	**1**	**-2.77**	**-2.59**	**1**	**5**	**-7.22**	**-8.59**
2	**2**	**-2.81**	**-5.25**	**2**	**6**	**-7.42**	**-13.92**
3	**3**	**-2.91**	**1.03**	**3**	**7**	**-8.98**	**-18.76**
4	**4**	**-3.79**	**-2.41**	**4**	**9**	**13.84**	**11.27**
5	**8**	**-3.89**	**-5.19**	**5**	**10**	**17.73**	**10.76**
6	**11**	**0.47**	**0.38**	**6**	**12**	**-4.43**	**-11.19**
7	**14**	**-4.49**	**-9.78**	**7**	**13**	**-7.34**	**-13.07**
8	**15**	**3.69**	**4.39**	**8**	**17**	**9.14**	**16.22**
9	**16**	**-2.89**	**-5.60**				
10	**18**	**-0.72**	**1.24**				
AVMR*		**4.49**	**9.78**			**17.73**	**18.76**
RMS		**3.11**	**4.65**			**10.31**	**13.33**
RMS_p		**5.59**				**16.85**	

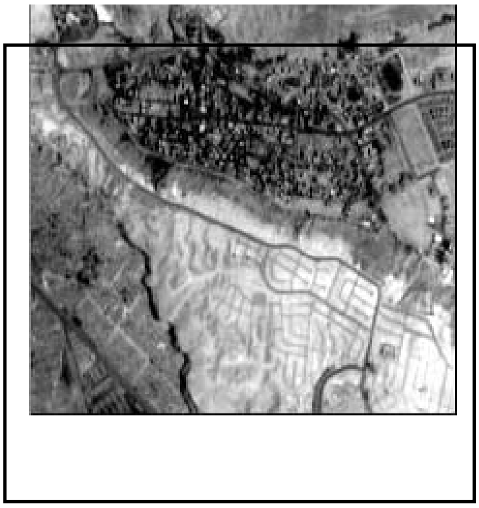
* AVMR = Absolute Value of Max. Error.

Table (6) & (7)

E, N Discrepancies for 10 Points on Flat Terrain
&
8 Points on Top of Buildings
(meters), Left Fused Image.

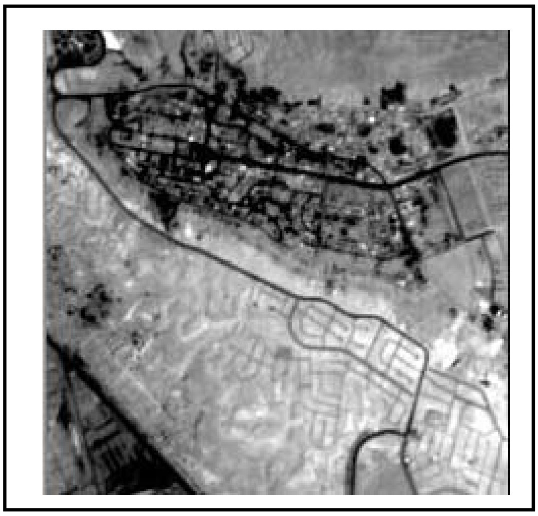
No.	Point ID	Δ E	Δ N	No.	Point ID	Δ E	Δ N
1	**1**	**-2.78**	**-3.04**	**1**	**5**	**-6.71**	**-8.19**
2	**2**	**-8.57**	**-3.64**	**2**	**6**	**-7.29**	**-13.58**
3	**3**	**-2.88**	**1.00**	**3**	**7**	**-8.92**	**-17.90**
4	**4**	**-2.83**	**-1.54**	**4**	**9**	**14.61**	**10.96**
5	**8**	**-3.77**	**-4.86**	**5**	**10**	**17.09**	**11.84**
6	**11**	**0.27**	**0.11**	**6**	**12**	**-4.49**	**-11.60**
7	**14**	**-3.64**	**-10.19**	**7**	**13**	**-7.38**	**-13.48**
8	**15**	**4.47**	**4.08**	**8**	**17**	**8.87**	**17.85**
9	**16**	**-3.94**	**-5.94**				
10	**18**	**-0.85**	**1.82**				
AVMR*		**8.57**	**10.19**		**17.09**	**17.85**	**17.09**
RMS		**4.01**	**4.57**		**10.23**	**13.54**	**10.23**
RMS_p		**6.08**				**16.97**	

* AVMR = Absolute Value of Max. Error.



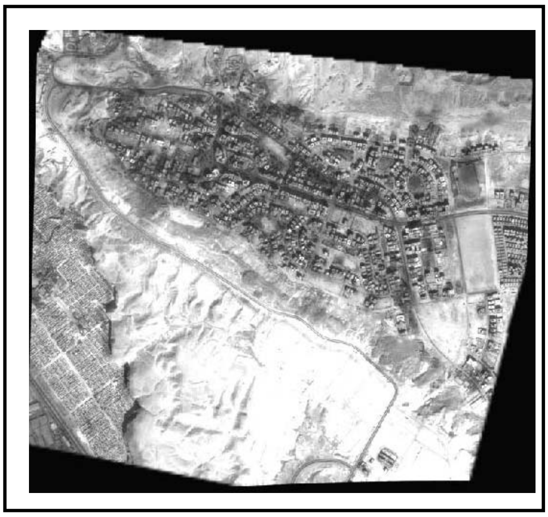
Figures (1) & (2)

Common Cut Area from Single IKONOS
&
Left SPOT Imageries



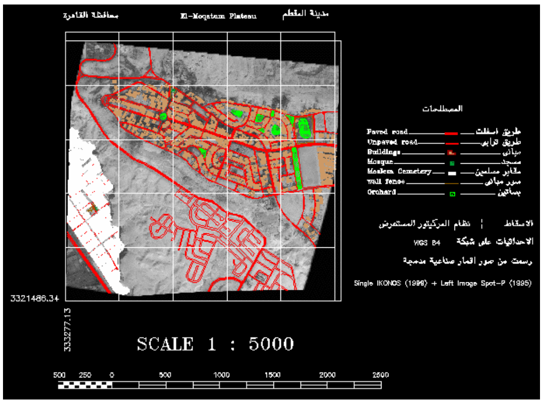
Figures (3) and (4)

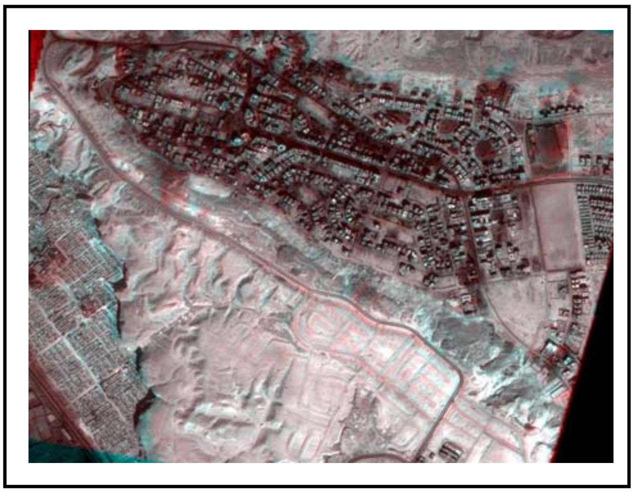
Common Cut Area from Right SPOT Imagery,
&
Location and Distribution of the 7 GCPs over IKONOS Raw Imagery



Figures (5) & (6)

Fused Images (Left SPOT and IKONOS)
&
Fused Image (Right SPOT and IKONOS)





Figures (7) & (8)

A Complete Topographic Map Enlarged to Scale 1:5000 Produced from the Fused Image (Left SPOT and IKONOS)
&
General View for the Complete Stereo Model Composed from the Two Fused Left and Right Images Superimposed Together

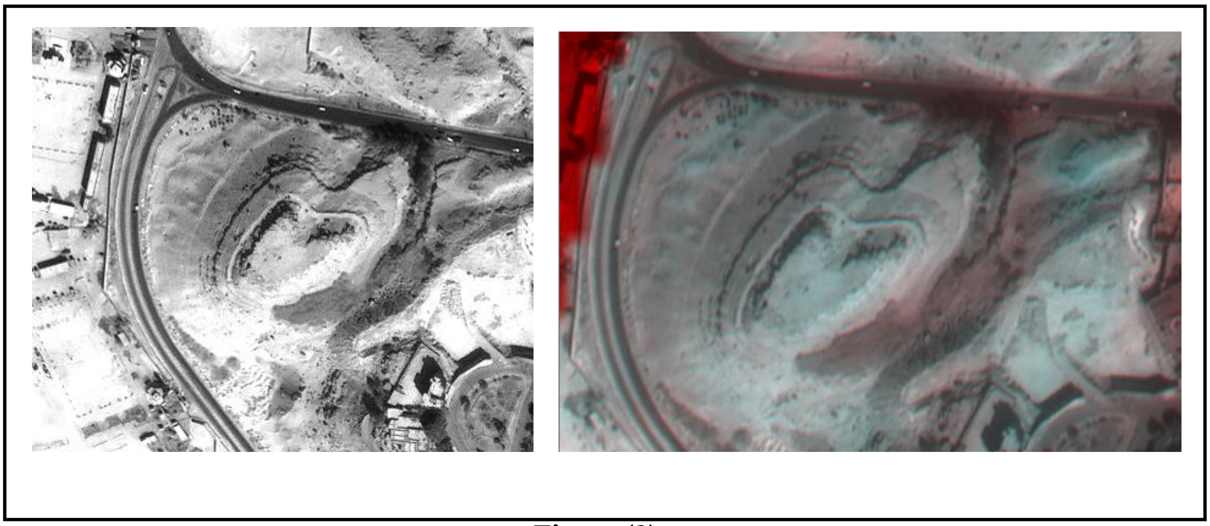


Figure (9)
Sample from the Single IKONOS Imagery and from the Stereo Model for the Same Hilly Area

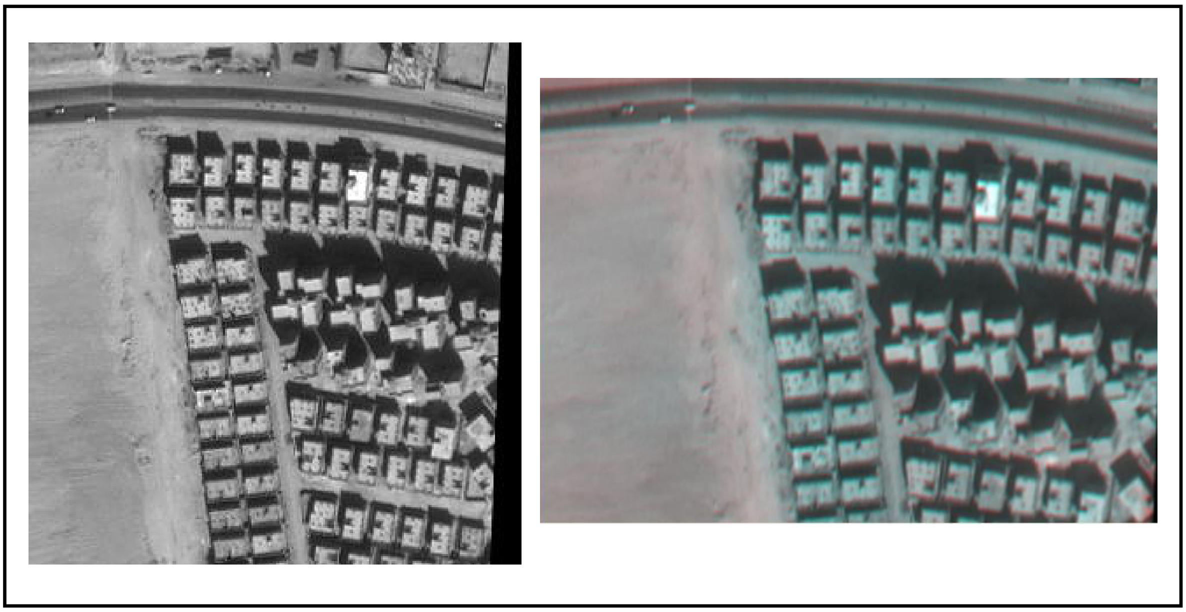


Figure (10)
Sample from the Single IKONOS Imagery and from the Stereo Model for the Same Building Area

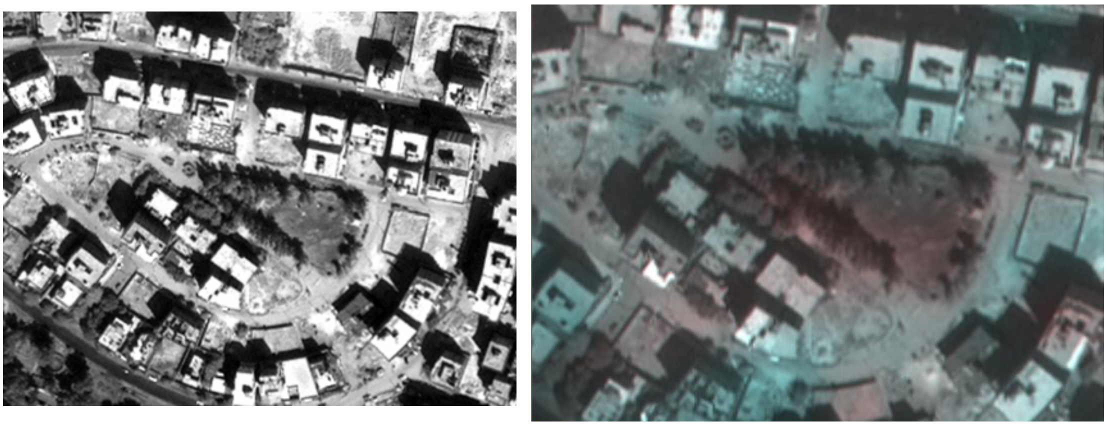


Figure (11)
Sample from the Single IKONOS Imagery and from the Stereo Model for the Same Green and Green Area

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BIOGRAPHICAL NOTES

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- B.Sc. Civil Engineering, June 1983,
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Supervisor assistant (1988) (photogrammetrist),
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* **PRACTICAL EXPERIENCE**:
- Aerial Photography (ZEISS RMK-TOP-15, LIDAR, Beach Craft 200 King Air),
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* **List of Publications**:
- Nassar, M. and Sharawi, A., 1996. "SPOT Satellite System: Theory and Practice". A paper presented at the 9th United Nations Regional Cartographic Conference for Africa, held in Addis Ababa, Ethiopia, Nov. 11-15, 1996.
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