

CHANGE DETECTION IN HISTORICAL CITY CENTERS USING MULTI-SOURCE DATA: THE CASE OF HISTORICAL CENTER OF NICOSIA - CYPRUS

Petros PATIAS¹, Dimitris KAIMARIS², Efstratios STYLIANIDIS²

Aristotle University of Thessaloniki, Greece

¹School of Rural and Surveying Engineering, patias@auth.gr

²School of Urban-Regional Planning and Development Engineering, kaimaris@auth.gr, sstyl@auth.gr

Keywords: Photogrammetry, Remote Sensing, Visualization, Spatial distribution, Nicosia

Abstract:

The development and expansion of the urban tissue of the historical capital of Cyprus Nicosia over the years is studied through historical documents, maps, archived aerial photographs and recent satellite imagery.

Documentation tools and the current technology of visualization is been used as a means for dissemination of the derived information to non-experts and the wide public.

The case of Nicosia is quite indicative for a big number of city centers suffering from a similar problem: to keep a balance between a long historical evolution and enhance the public awareness from one hand, and revitalize a living urban center on the other hand. We feel that the contribution of photogrammetry, remote sensing and visualization techniques can be enormous and we intent to make a case through the Nicosia case study.

1. Introduction

Land use patterns in Cyprus are changing following the pathway of other western countries, ignoring Mediterranean cities' urban tradition and values. However, at the historical city centers seems that not such an effect has been occurred. One of these examples is the historical centre of Nicosia, the capital of Cyprus.

The growth of the historic urban fabric of Nicosia, the capital of Cyprus, over the years is studied through heterogeneous data; historical documents, maps, archived aerial photographs and recent satellite imagery.

The case of Nicosia is quite indicative of a big number of city centers suffering from a similar problem: to keep a balance between a long historical evolution and enhance the public awareness from one hand, and revitalize a living urban center on the other hand.

The contribution of photogrammetry, remote sensing and visualization techniques can be enormous and the paper aims to make a case through the Nicosia case study. This paper also aims to map the 'change detection' in a region that, even though is excluded from the economic globalizing processes, is influenced by cultural trends.

2. The use of multi-source data

In dealing with historical city centers and their evolution in time, it is inevitable that data from different sources should be used. Maps and Images document specific evolution phases in time, they have their own geometric integrity (which sometimes reflects the technology used at that time), and they are characterized by specific thematic or radiometric content.

The main idea in using multi-source data is to combine different sources of information in order to be able to study features and characteristics, which no source alone can provide. Another, even more important reason is that studying changes over time, one cannot avoid using different sources of multi-temporal data (eg. satellite imagery are only recent, while aerial photography has been used long ago) [1-3].

Historical Map

From all three (ie. satellite imagery, aerial photography and maps), maps are the oldest. The older they are, the less accurate are too and, in general, they constitute a “generalized” view of the reality, meaning that they map only what the cartographer wished to emphasize, and, to this respect, their scale reflects both the amount of information and the geometric integrity.

Needless to say that old maps are in hard copy form and therefore their scanning is the only means to transform them in digital form, compatible with other sources’ data. In regards to their geometric integrity one has to bear in mind that they suffer from (sometimes large) distortions due to the material changes and on top of these they also suffer from scanning imperfections [4].

Aerial photography

Aerial photography is in use for more than 200 years and therefore it constitutes an important contribution to the study of historical changes.

As with maps, aerial photographs also suffer from film and lens distortions, and, once scanned, also from scanner errors. However, unlike maps, they are characterized by a solid geometric model (ie. central projection), which makes their processing easier.

Moreover, again unlike maps, they document the reality without any generalization at all.

The radiometric content of aerial photography generally refers to visible range only of the electromagnetic spectrum, which is mapped in grey values. This is especially true for historical archives, although recently this is changing with the use of both color aerial photography and digital sensors sensitive also to the infrared or even thermal region of the spectrum.

Very-high resolution satellite imagery

Panchromatic mode is operating in visible region (about 0.4 μ m), while multispectral up to thermal region (about 15 μ m) of the spectrum [1-3].

3. Change detection procedure

The first step in change detection is to transform all the data (i.e maps and images) to the same reference frame. This procedure, called “geo-referencing”, is a strict mathematical transformation, which takes into account the map scale and projection, the central projection of the aerial photographs and the “quasi”-central projection of the satellite images. The outputs of these geometrical transformations are maps and images referring to the same coordinate system and being free of internal (ie. sensor/scanner) errors and distortions.

The second step is to identify the feature to be studied. Normally in urban environments, these features are buildings, roads, vegetation or other environmental characteristics. Manual image interpretation techniques are always useful but they are time consuming, costly and many times erroneous. Therefore automatic or semi-automatic techniques are always desirable.

Enriching radiometric content with geometric integrity

Georeferencing is a transformational geometric procedure of scaling, rotating, translating and de-skewing an image to match a specific size and position. The expression “georeferencing” is well-known to geo-community, since the term was initially used to illustrate the method of referencing a map image to a geographic location.

Thereby, in order to effectively use data from different sources, the need for bringing them together by means of a common referencing system is obvious. This is applicable to information that is created with GIS, but also to information that originates from other forms such as paper (historical) maps and aerial photographs.

There are many tools that make it easy to transform raster images to fit a geodetic control framework and several different formats for such images. Some of these image formats have the ability of storing the coordinate system metadata with the image information in the same file. Some others carry the georeferencing information in separate files.

Classification of satellite imagery

In order to effectively use data from different sources, the need for bringing them together by means of a common referencing system is obvious. This is applicable to information that is created with GIS, but also to information that originates from other forms such as paper (historical) maps and aerial photographs. This page discusses the process of applying a real-world coordinate system to images. Here is a short list of reasons that this is worth learning about.

4. The case study of Nicosia – Cyprus

Nicosia, also known as Lefkosia, is the capital and largest city of Cyprus. The city is located almost in the centre of the island; it is the seat of government as well as the main business centre. Nicosia was known as Ledra in ancient times. The city was rebuilt by Lefkos, son of Ptolemy I around 300 BC, in Hellenic and Roman times was a small, unimportant town, also known as Lefkothea.

The city has been destroyed more than once by conquerors, but the city still has enough bits and pieces to recall its past. The Venetian city wall (clearly illustrated on the satellite image of Figure 1) which was constructed between 1567 and 1570 is one of these leftovers. The 4,5m thick wall used to have three gates and the historical centre is clearly present inside the walls. However, the modern city has grown beyond the walls.

Multi-source and multi-temporal data and their geo-referencing

For the georeferencing of the historical geographical data, an orthorectified satellite image QuickBird-2 was used (pixel size: 0,6m, LTM – Local Transverse Mercator which is the local coordinate system) of 2006 (fig. 1).

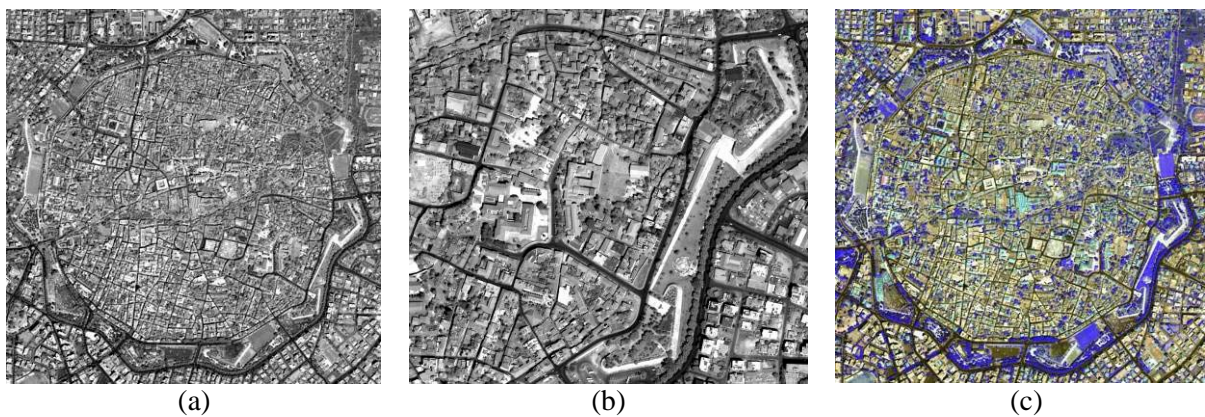


Figure 1: Quickbird panchromatic satellite imagery with resolution of 0.6m of 2006 (a) An overall view, (b) detail view, (c) Fused (panchromatic + multispectral) imagery with resolution of 0.6m. Note that the red band has been replaced by the infrared band, in order to enhance the vegetation areas (shown here in blue).

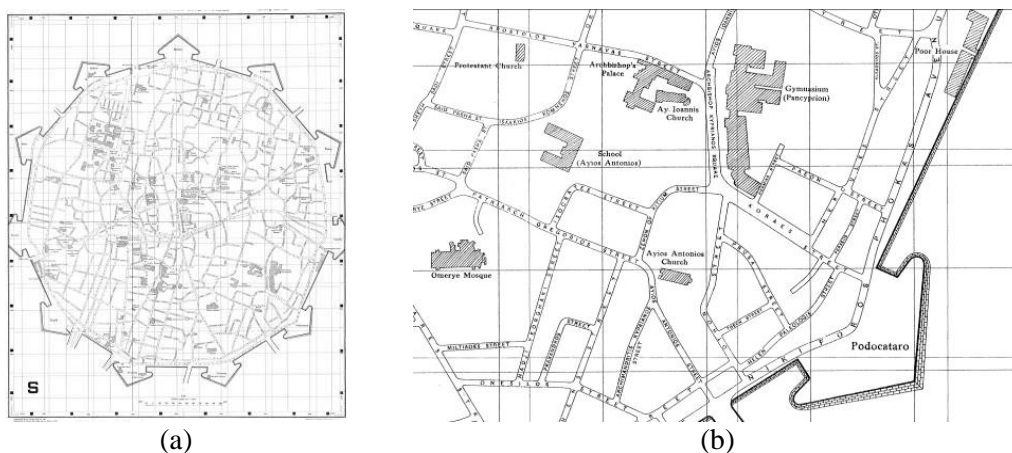


Figure 2: Map of Nicosia, 1956, scale 1:2,000. (a) An overall view, (b) detail view.

The historical map of Nicosia (Geographical Section General Staff No. 4861, Published by D. Survey, War Office and Air Ministry, 1956, fig. 2), in scale of 1:2,000, was digitized in 400dpi (1pixel=13cm on the ground). For the polynomial transformation of the 2nd grade (accuracy transformation ~1,5m) some well-preserved constructions, such as streets, buildings, etc., were used as control points. For the study area four historical aerial photographs (dated 02/10/1963, scale 1:5,400, source: Department of Lands and Surveys), which were digitized in 1,200dpi (1pixel = 11cm on ground), were also used. For their projective transformation control points were collected from the contemporary orthorectified satellite image QuickBird-2 (accuracies of transformation 0,40-0,7m). The spatial resolution of the orthorectified aerial photographs mosaic is 0,7m (fig. 3).

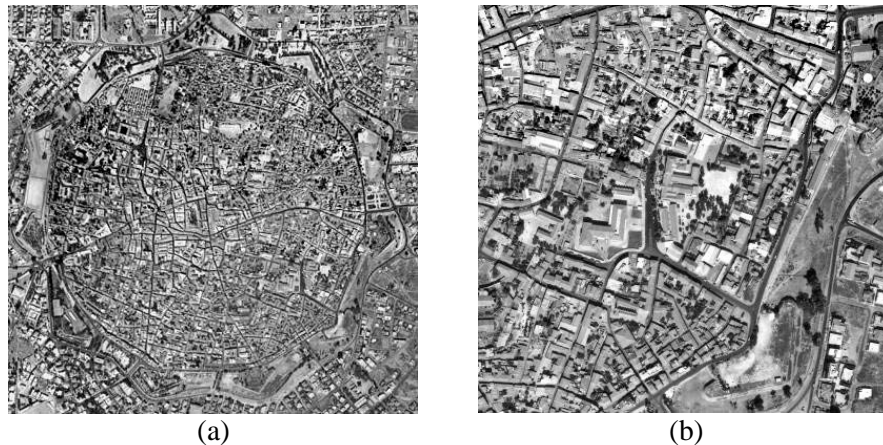


Figure 3: Mosaic rectified aerial photographs of Nicosia, 1963. (a) An overall view, (b) detail view

Image classification procedure

A Supervised Classification of the satellite image QuickBird-2 was used for the identification of five object classes: Shadow, Asphalt, Vegetation, Ground, Buildings. A total of 203 pixels have been used for accuracy assessment (table 1). The Overall Classification Accuracy (OCV) it is 85.71% and the Overall Kappa Statistics (OKS) it is 0.8539.

Table 1: Classification Accuracy assessment report

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Vegetation	16	16	16	100,00%	100,00%
Asphalt	30	27	26	86,67%	96,30%
Ground	38	44	34	89,47%	77,27%
Buildings	108	106	89	82,41%	83,96%
Shadow	11	10	9	81,82%	90,00%
Totals	203	203	174		

The built area (Asphalt, Buildings and Shadow) covers the 65% and the non-built (Vegetation and Ground) the 35% of the total study area (fig. 4 and table 2).

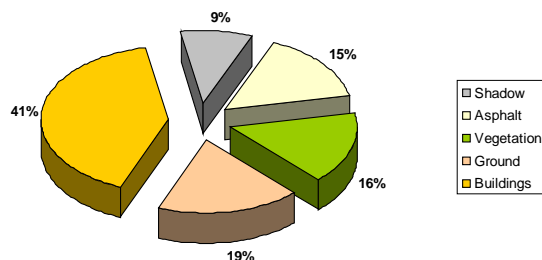


Figure 4: Classification of land use.

Table 2: Land use and number of pixel.

Type of Land use	Number of pixels
Shadow	776,993
Asphalt	1,300,826
Vegetation	1,334,783
Ground	1,564,770
Buildings	3,455,840
Total	8,433,212

Detection of changes by photo interpretation and amount of changes

The comparison of the constructions, which were mapped in the historical map of 1956 with the aerial photographs of the 1963 (fig. 5) revealed that 6 from a total of 106 buildings of religious, administrative and commercial use, were destroyed and either new buildings were constructed or part of the area was remained unstructured (fig. 7). Besides, 1 road was transformed to built area and 7 new roads were constructed.

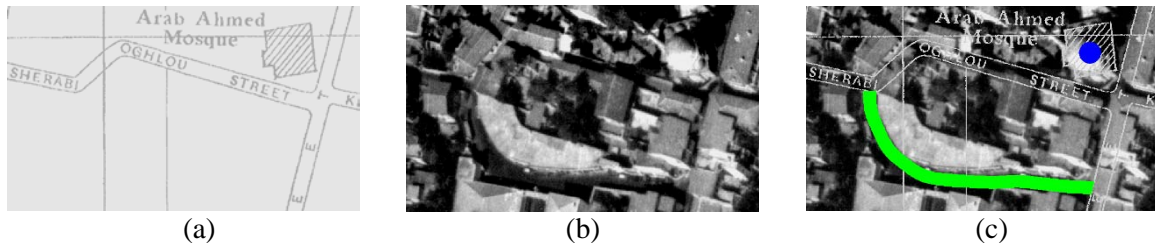


Figure 5: Comparison of geographical data. (a) Map of 1956, (b) aerial photograph of 1963 in scale 1:5,400, (c) Overlay: Inside the blue circle there is a preserved building and with a green line a new road.

Additionally, the comparison of the historical map of 1956 with the satellite image QuickBird-2 (fig. 6), allowed the detection of destruction of 9 buildings, which were replaced by new constructions whereas some areas remained unbuilt. Additionally, after the 1963, 15 roads were transformed to buildings or unbuilt areas and 7 new roads were constructed.

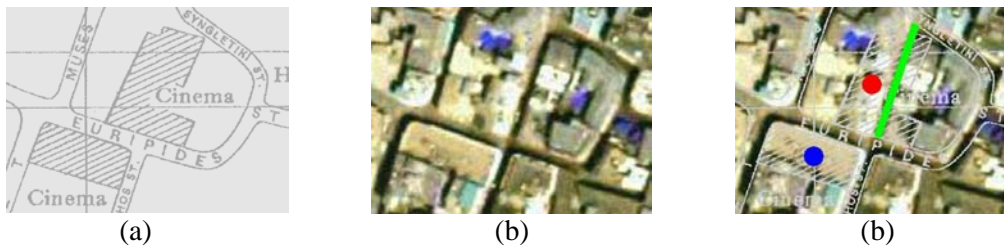


Figure 6. Comparison of geographical data. (a) Map of 1956, (b) QuickBird-2 2006, (c) Overlay: In blue circle a preserved building, in red circle a building that was demolished and with green line a new road.

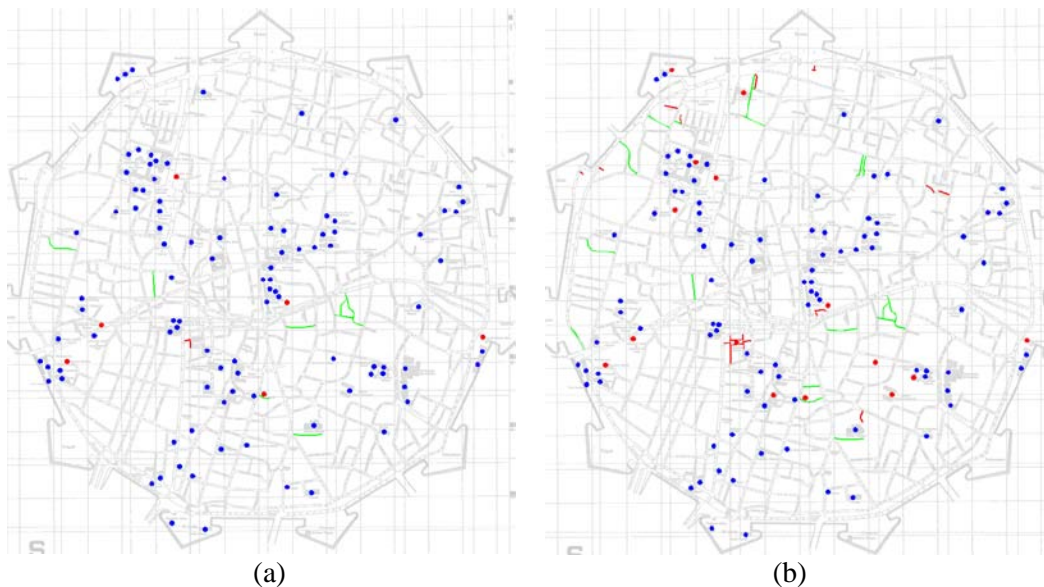


Figure 7: Transformation of the built area, (a) 1956-1963 and (b) 1956-2006. Background is the historical map of 1956, in scale 1:2,000. In blue circles the preserved buildings and in red circles buildings that do not exist in the corresponding geographical data. With green lines there are new roads and with red line the roads that do not exist in the corresponding geographical data.

5. Conclusions

The digital processing of the diachronic geographical data permits the tracing of changes over time in historical cities. The study resulted that from 1956 to 2006, the 86% of the historical buildings were preserved in the urban area inside the walls, whereas the area of the road network was not changed significantly, because of the small number and the cover area of the new roads (14) and of the ones that changed their function (16). Consequently, it is almost completely preserved the initial urban design and furthermore a part of our cultural heritage was well preserved.

6. References

- [1] Holland, D.H., Boyd, D.S., Marshall, P.: *Updating topographic mapping in Great Britain using imagery from high-resolution satellite sensors*, ISPRS Journal of Photogrammetry & Remote Sensing, vol. 60 (2006), 212-223.
- [2] Li, X.: *A four-component Efficiency Index for assessing land development using Remote Sensing and GIS*, Photogrammetric Engineering & Remote Sensing, vol. 71, No. 1 (2005), 47-57.
- [3] Matikainen, L., Hyypä, J., Engdahl M.: *Mapping built-up areas from multitemporal interferometric SAR images – A segment-based approach*, Photogrammetric Engineering & Remote Sensing, vol. 72, No. 6 (2006), 701-714.
- [4] Kaimaris, D., Georgoula O., Karadedos G.: *Historical maps and archaeological research*, Proceedings of 8th National Conference of Cartography *Cartography and good leaving*, Thessaloniki, Greece, November 2006, 51-62.