

# VIRTUAL INVERSE PHOTOGRAMMETRY

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## ABSTRACT

Inverse Photogrammetry is used as a tool for visualizing projected developments or past situations within an existing environment. Usually traditional photogrammetric practice is followed with respect to data input, processing and output of inverse photogrammetric products. Since the purpose is visual inspection and overview rather than strict metric needs, fast and cheap methods for both the data to be gathered and the photogrammetric processing are favorable. The work is an attempt to meet these requirements by using video recording for data input and user friendly software for data processing. The importance of the final presentation of the results suggests the use of a virtual computer environment with various visualization capabilities, more advanced than the ones used for the purposes of traditional Inverse Photogrammetry.

## 1. INTRODUCTION

Inverse Photogrammetry, as the term implies, is an inverse operation of the custom photogrammetric procedure. While in the latter the purpose is to reconstruct the geometry of an object based on perspective views of this object (recorded on photographs), the purpose of Inverse Photogrammetry is to recreate a perspective view of an object when its geometry is known in 3D space. This is particularly useful in architectural or civil engineering projects, where a planned construction, such as a new building, can be incorporated in existing photographs of the site of the project, on the basis of its planned position within the area. In this way the new situation can be visualized before its realization and the result can be examined from aesthetic, morphological etc. point of view.

The procedure of Inverse Photogrammetry involves plotting the planned construction on a photographic perspective taken from a certain point of view in a certain direction (Carbonnell, 1989). This can be done if one knows the (X, Y, Z) coordinates of characteristic points of the future construction, the (X, Y, Z) coordinates of the point of view, the direction of the camera axis and the camera constant. Applying the collinearity condition, the image

coordinates of the respective construction points can be calculated and plotted on the photo.

The typical steps of such applications, which have been used for long in Photogrammetry, are (Yacoumelos, 1970):

- Acquisition of the 3D geometry of the construction.
- Photographing the surrounding area from suitable viewpoints.
- Construction of the 3D perspective of the object.
- Incorporation of the object in the photograph(s) or even in a stereo pair of photographs.
- Examination (in monoscopic or stereoscopic viewing) of the result.

A similar technique known as the “reverse projection” technique has also been used in (non-topographic) photogrammetric applications, such as accident scene reconstruction (see, for example, Whitnall and Moffitt, 1989).

All the previous have traditionally been applied - by photomontage (i.e. photo mounting)- on photographs taken from a certain perspec-

tive. This means that in order to be able to examine a future situation from various viewpoints within its surrounding environment several shots have to be taken and the inverse photogrammetric technique has to be applied repetitively, i.e. for each shot. Furthermore, in order to be able to have an overview of a project within its broader geographic area, airphotographs should be actually available.

A CAD graphics environment, not only for scene reconstruction, but also for the final presentation can offer an alternative solution to such limitations of the traditional method. In a CAD environment possibilities such as the examination of the scene from any desired point of view, the creation of fly-through etc. are common practice. Furthermore, by adding color, texture and shading to both the existing and the new constructions photorealistic visualizations are possible, which can give a photographic impression to the product.

## 2. STEPS AND TOOLS FOR SCENE RECONSTRUCTION

Given that usually the products of Inverse Photogrammetry are a means for satisfying visual inspection and overview purposes rather than strict metric needs, it would be meaningful to generate the required product as efficiently as possible. Favorable, therefore, are fast and cheap methods, with the minimum possible requirements for both the data to be gathered and the photogrammetric processing to be followed. On the other hand the final product should give the impression of a photograph as much as possible; it should also be available in a suitable environment for the users to examine.

In the present work an attempt to combine the above principles is made, by means of an example similar to the traditional inverse photogrammetric requirements and procedures. Nevertheless, the tools used and consequently the steps followed are adapted to less traditional practice. More specifically, the objective has been to incorporate a new construction in an existing area of a city (Thessaloniki in this case) and visualize the new situation. Mainly two points distinguish the traditional method from the one followed here: data input and presentation of results. For the latter the obvious choice of a virtual environment – a 3D CAD program with photorealistic possibilities, camera simulation and animation- was made. For data collection video recording was used,

since it offers a fast, flexible and cheap way of data input.

Therefore, the basic steps that are followed in an inverse photogrammetric procedure (as stated in the previous paragraph) are adapted - with respect to procedures and tools - as follows:

- **Acquisition of the 3D geometry of the construction**

This is necessary to know, as is also the geographic location where it will be situated. A 3D CAD files, therefore is needed in practice.

- **Photographing the surrounding area from suitable viewpoints**

A video camera is used to record the area. More specifically, recordings are made from a number of viewpoints, so that all the (existing) elements of the area can be later reconstructed (e.g. buildings and their facades). Also, a video recording of the spot where the new construction is to be placed has to be made -from suitable viewpoint(s)- if one wishes to combine CAD and video in a way similar to the traditional one, as will be explained in a later paragraph.

- **Construction of the 3D perspective of the object**

There is no need for this step anymore, since the 3D CAD file is available, as mentioned in the first step. The perspective will depend on any viewpoint the user chooses.

- **Incorporation of the object in the photograph(s) or even in a stereo pair of photographs**

Since the substitute of the (future) object is its CAD file, this can be easily imported in the CAD file of the surrounding area. The substitute of the “photograph” of the traditional approach is exactly this (3D) CAD file of the area. This, however (i.e. the construction of the CAD of the surrounding area in 3D) is an extra step that has to be carried out. It is assumed that such a 3D file is available to the users (e.g. via the municipality). But even if this is not the case (which is more likely, in practice), it is possible to reconstruct the 3D geometry from a 2D map (easily available e.g. from the municipal or other map issuing authorities) and the various available images (i.e. the video frames). This can be done by making use of suitable,

user friendly software for generation of 3D models from photographs. After the 3D-wireframe model is ready, texture mapping is applied, by adding the facades of constructions. These facades, (which are, again, recorded on the various video frames) are photogrammetrically rectified before being attached on the respective surfaces.

- **Examination (in monoscopic or stereoscopic viewing) of the result**

By making use of a CAD environment a variety of ways for visualizing the result is available. These include: changing the viewpoint of observation for examination of the new project from any point of view (which is actually the objective of traditional Inverse Photogrammetry in the first place), applying photorealism (to simulate the photo(s) of the traditional process), generation of stereoscopic views. Furthermore it is possible to simulate photographic shots within the virtual environment of the 3D file, by setting and adjusting a virtual camera, which can be positioned and oriented in any manner required within the space of the design file. Depending on the settings, the respective portion of the file is displayed in perspective projection. Various "lenses" (i.e. input parameters for focal length and angle) are also available to modify the resulting image.

### 3. AN EXAMPLE IN THESSALONIKI (IMPLEMENTATION)

The steps outlined above were followed in an application that was carried out for a spot in the city of Thessaloniki. An area in the new sea promenade of the city was chosen as a test case. The lack of real data about any planned project led to the choice of a fictional development: an extension of the promenade into the sea and the construction of a building for general public use (e.g. recreation, cultural etc). In Fig. 1 an overview of the area used in the example is given as a 2D drawing: the left picture shows the existing situation and the right one the area with the future plan included.

A CAD software program (*Microstation* by *Bentley Systems Inc.*) was used for 3D scene reconstruction and visualization of the results. Since no 3D CAD of the area was directly available this had to be constructed, mainly on the basis of the video recording and a topographic plan of the area.

As mentioned previously, data collection was carried out by means of video recording of the area. A *CCD-V600E Video Hi8* handycam video camera/recorder (camcorder) was used. Apart from the already mentioned low cost and flexibility of video recording, an immediate advantage is the presence of overlap in the video images. This can help overcome the unavoidable difficulty of the limited coverage in images, especially when recording from short distances (e.g. because of narrow streets). The video recording was downloaded in a number of digital video files and images, with the help of the software package *Adobe Premiere LE*.

For the planimetry of the area a topographic plan (scale 1:500) available from the Thessaloniki Municipality was used. The 3D geometry of the area can then be generated from the 2D topographic plan and the suitable still snapshots (i.e. still video images). An easy to use software program (*3D Builder* by *3D Construction Company*) was used for this purpose. *3D Builder* generates models from images and is designed for generic (not necessarily only photogrammetric) use. Its calculations are based on the perspective characteristics of the central projection (vanishing points). Therefore no need for control points is necessary. After the 3D model was generated the facades of the buildings were attached on the respective surfaces, for a more realistic impression. These facades had, of course, to be rectified first. The photogrammetric rectifications were carried out with the help of the software package *I/RAS C* by *Intergraph Corp.* Finally, the CAD environment is used for the visualization of results. An overview of the generated file, showing the existing and the planned area in 3D is given in Fig. 2.

The purpose of attempting to apply Inverse Photogrammetry in a virtual environment is mainly twofold:

1. Reconstruct and examine a scene in CAD in order to overcome the limitations of the traditional method. The CAD environment offers more flexibility in visualizing results. In Fig. 3 various views of the area after project construction are shown, from various viewpoints. On these, different settings have been used (e.g. different lenses, viewpoints, simulation of vegetation, applying shadows and texture etc.)
2. Implement a parallel of the traditional procedure in the new environment. This means that it should be possible to create products similar to the traditional ones, in other words, to mount the new situation on

an image taken before the new construction is implemented. As mentioned previously, the presentation environment used for the example offers various visualization options. The one that is particularly useful for this specific purpose is the possibility to simulate photographic shots within the virtual environment of the 3D file. Setting and adjusting a virtual camera, for which position and target points are defined in 3D space, does this; the respective part of the design file is then displayed in perspective, with the new situation shown. If an image (of the existing situation) taken from the same viewpoint and to the same direction is available, it is then possible to overlay the CAD on the image. For the present example images were available as frames of a video sequence. In Fig. 4 an output of the above procedure is shown, for two frames of a video sequence showing the spot where the new construction is to be located. After mounting is performed for a number of frames, it is easily possible to create a new video sequence (the CAD software has the option of creating video files). In this way, a dynamic overview of the area with the new situation can be displayed.

#### 4. CONCLUSIONS

The attempt to apply Inverse Photogrammetry in a virtual environment, using new tools and having in mind the objectives stated previously in the paper, has certain advantages; some limitations are, however, unavoidable. Both positive and negative aspects can be summarized in terms of: *Data capture, Equipment and Tools, and Presentation of results.*

Most of the difficulties encountered are related to limitations and obstacles present during *Data capture*. Narrow streets, for instance, seem to be a major obstacle when recording buildings (A photomosaic from overlapping images can offer a solution, but increases the amount of work. Other solutions, such as the use of wide-angle lenses, are assumed not available for a common video camcorder). Other commonly encountered obstacles include lampposts, columns, tree-trunks and foliage, parked cars etc. Some of these are impossible to eliminate from images; often, therefore, they are recorded as part of building facades.

Both *Equipment* for data capture (video) and *Tools* for data processing (i.e. software) are

easy to use, flexible and low cost. Although a variety of software tools was used for the step by step processing of the data, these are all general purpose, user-friendly, inexpensive and nowadays commonly available.

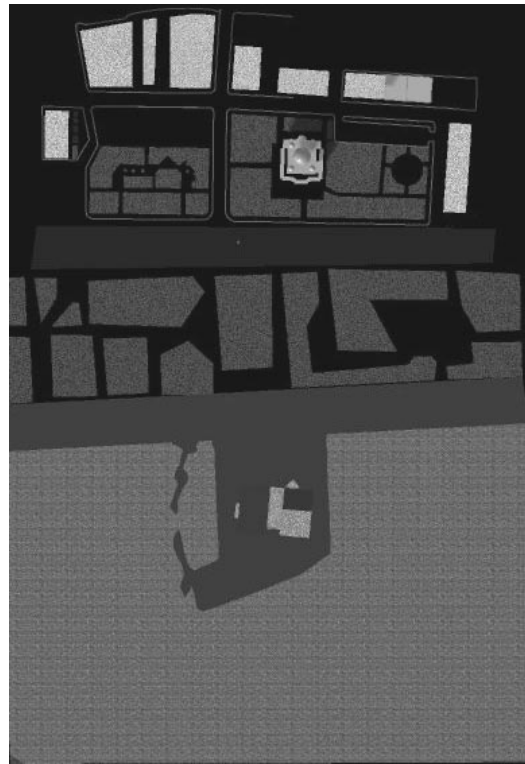
The strongest point of the virtual approach for Inverse Photogrammetry lies in the *Presentation* capabilities offered by a CAD environment, as the one used here. The result has many options for overview of a project within a broader geographic area, although the data collection is done terrestrially. If this overview had to be generated traditionally, i.e. not in a CAD, (oblique) air-photos should be necessary as input. Furthermore realism is simulated to a satisfactory degree and the existing photorealistic effects can be manipulated at will (e.g. solar study, view of vegetation in various seasons etc.). Another advantage is the possibility offered by the CAD environment to reconstruct traditional inverse photogrammetric products (photo mountings) and even expand them through new products (i.e. video sequence of the new situation).

#### Acknowledgement

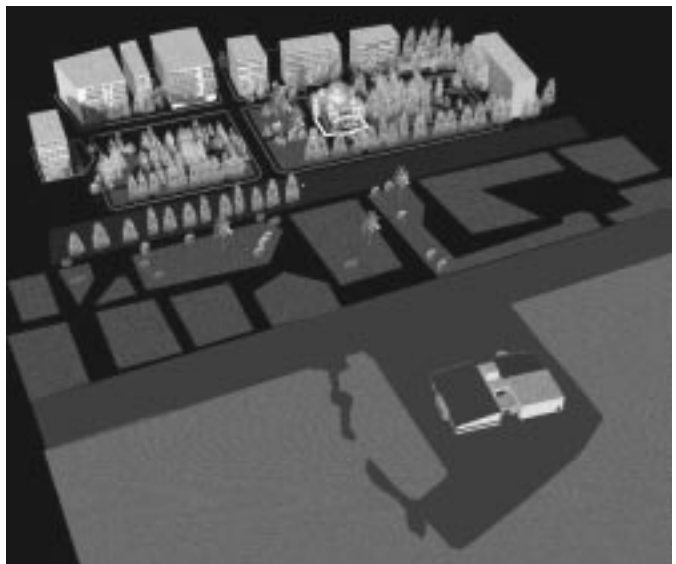
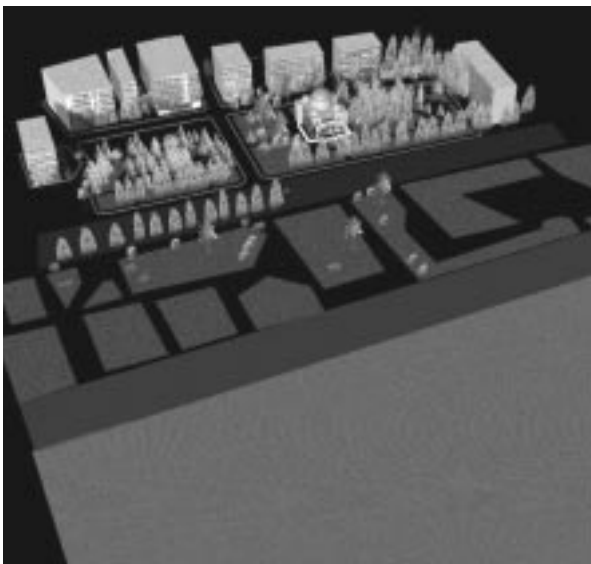
The authors wish to thank the Topographic Division of the Municipality of Thessaloniki for providing a base map of the area, upon which the 3D CAD file of the existing situation was constructed.

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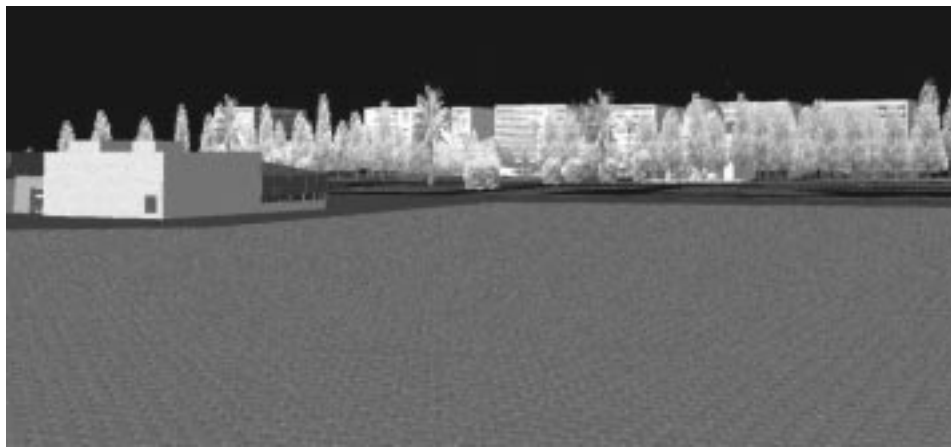
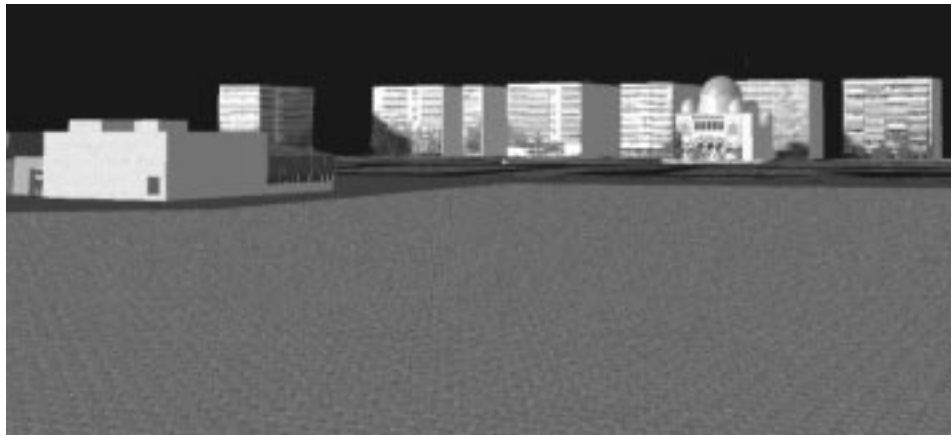
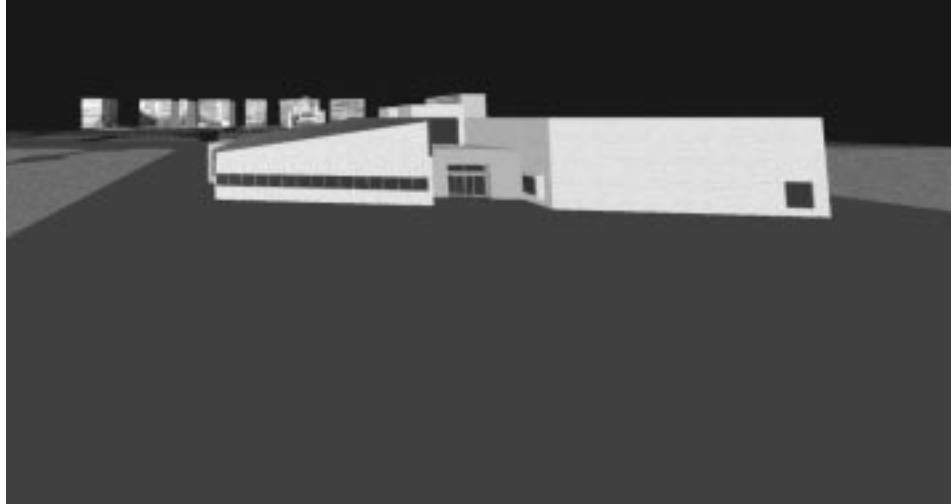
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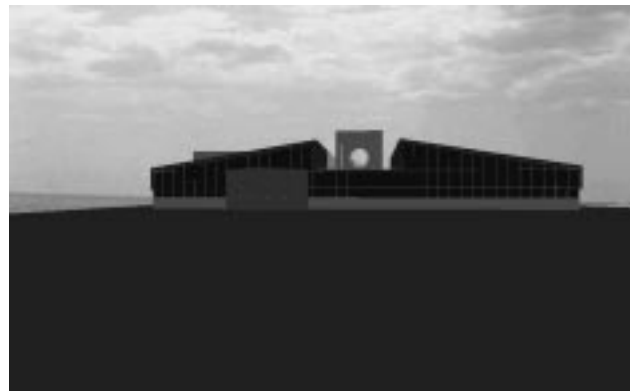
*Figure 1: Overview of the example area (top view): left before the development and right with the future plan included*



*Figure 2: 3D views of the area: left before and right after the development- looking from the sea.*



*Figure 3: The new situation from various viewpoints and with different display settings.*



*Figure 4: "Mounting" the CAD into video: on top the original video frames, below the new situation inserted in the frames.*