3D DETAILED RECONSTRUCTION OF A DEMOLISHED BUILDING BY USING OLD PHOTOGRAPHS

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ABSTRACT

In many cases, when the restoration or the rebuilding of impotrant old buildings, that are partially or totally destroyed, is needed, or when the documentation of destroyed monuments is attempted, old amateur pictures usally consist the most significant source of information. The lack of control points or other metric information makes the use of such pictures very difficult or even impossible for the compilation of detailed, high-accuracy plans. The structure of the building/object and the availability or not of some additional information play a critical role for a successful result.
In this paper, an application on an already demolished 3-floor building of interesting architecture is presented. The combination of old airphotos, old terrestrial amateur pictures and some old plans of parts of the building, gave a 3D digital detailed restitution of the building by applying analytical and digital photogrammetric methods and using a CAD package. The whole proceedure and methodology followed are given and the graphic results together with the degree of accuracy achieved are shown.

1. INTRODUCTION

The compilation of a proper, detailed and reliable survey is of great importance for the study, conservation, protection or restoration of any type of monument. In the case that the particular monument does not exist any more, the compilation of the plans based on measurements and interpretation of old imagery seams to be the only solution. Yet, in most of these cases the images have been taken by amateur cameras for various purposes and above all no control points or other geodetic measurements are available.

A similar situation is of a building that in the past was used as the Town Hall of Pireas, the greatest harbour of Greece, very close to Athens. This building was founded in 1869, by the seaside close to the central harbour, and its construction was finished by 1874. It was a big 3-floor building of significant architecture. Its longest dimensions were 22.65 x 27.90 m, its ceilings were of varying hights and in the center there was a small tower-clock (see Figure 1). Since 1885, until its demolition in 1968, it used to be the Town Hall and the Municipality Services Building. Today, at the same area there is a park.

In 1994 the new local authorities have planned a project to rebuild the old building at its original location following its initial shape, size and architecture. For the better study of the project, a digital 3D representation of the building was decided to be necessary. Also detailed facade plans of all sides and horizontal sections in desired levels were of crusial importance for the reconstruction. The only possible solution for the achievement of these plans is the "photogrammetric" use of some existing old amateur pictures / post-cards of the early time of the building, which were found in the municipality archives and in other private collections.

2. COLLECTION OF AVAILABLE INFORMATION

The first step of this work was the research of any existing available information/material that might contribute to the definition of the metric information concerning the building. The systematic and careful research of all possible sources of information (that is the Historical Archive of the Municipality of Pireas, private collections, special exibitions, antique shops, old airphotos of the area of interest, old urban planning maps etc) resulted to the followings:

a. Several close-range amateur pictures, most of them post-cards, of the 4 sides of the building, taken from various points of view, on various scales and on dates varying from the beginning of the century until the date of the building's demolition. The most important of them were properly magnified and reproduced, so that reliable measurements were taken:
   - two of them were of the southern side
   - one of the northern side
   - one of the western side
   - one of the eastern side
   - one of the northeastern side and
   - one of the southeastern side
b. vertical and oblique airphotographs of the area during the period of the 1950's and the 1960's. Only one pair of vertical airphotographs was proved useful for photogrammetric measuring. It was taken in 1965, at a scale of about 1:6.000
c. paper photocopies of six old plans of the building, in moderate condition, which are:
   - topographic diagram of the area of the building at a scale of 1:100, compiled in 1957
   - facade plan of the eastern and western side of the building at a scale of 1:50, compiled in 1921
   - plan of the southern facade at a scale of 1:50, compiled in 1921
   - old planimetry of the basement at a scale of 1:50, which was done as a proposal for changing the use of the building from Town Hall to a Nautical Museam
   - planimetry of the internal area of the first floor at a scale of 1:50
   - planimetry of the internal half area of the second floor at a scale of 1:50.

It must be mentioned that the two existing old plans of the facades have serious differences when compared with the related photographs, the most important of them are referred to

- the construction which existed on the upper part of the western side and is not shown on the facade plans

Figure 1. Old amateur photograph of the northeastern side of the building

- the windows which are shown on the upper part of the western side and in fact never constructed
- the structure of the tile ceilings instead of cement-made ones on the eastern and western side of the building
- the structure of a ventilator on the ceiling of the tower-clock, which is not shown in any one of the facades
- certain details on the sides of the tower-clock
- certain differences on the windows.

Besides, no other plan of the northern side of the building was found.

3. PHOTOGRAMMETRIC DATA PROCESSING

The determination of the necessary digital data (3D coordinates of characteristic points) for the completion and the correction of the existing plans of the facades is accomplished. The procedure followed consists of

- analytical processing of the stereopair of airphotos and
- digital rectification of various planes of the facades on the amateur pictures.

3.1 Analytical Processing of the airphotos

The X, Y, Z coordinates of the main characteristic points of the building, which were recognisable on the stereopair of airphotos of 1965, such as the corners of the building in various hights, on the balconies, ceilings, clock etc, were determined. The coordinate calculation was made on an analytical photogrammetric instrument. For the orientation of the stereopair the coordinates of 5 control points were measured by field surveying methods with an accuracy of a few centimeters. These control points are clearly defined, easily recognisable on the airphotos, located on the surrounding area of the building and belong to permanent structures that have remained unchanged since 1965. The characteristic points of the building that have been determined by stereorestitution are 120 in total and their coordinates have been calculated with an accuracy of 15-25 μm on the photo scale, or of 10-15 cm on the ground.

3.2 Digital Rectifications

Digital Rectifications of all planes of each of the four sides of the building have been accomplished by using the calculated coordinates of the characteristic points and metric information derived from the existing plans. The hardware used was a standard IBM-compatible PC with 80486 microprocessor and 8 Mb of RAM.

For this purpose, the seven forementioned most important amateur photos were scanned with a 600 dpi resolution. Since each side of the building consists of more than five planes (see Fig. 2 & 6), occasionally certain sides had to be produced by a combination of rectified planes taken from more than one pictures, in order to avoid hidden parts or large tilts or parts of small scale. The scales of the scanned photos are between 1:100 and 1:300. Since a magnified papercopy was used the image quality of the analog photos was comparatively poor, so a careful radiometric image processing of the scanned images (contrast and brightness enhancement, edge detection etc) was made.

In most rectification planes the determination of control points was impossible, because there was a difficulty in

Fig. 2 Photograph of the western side of the building

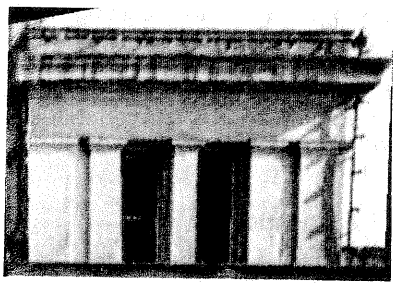
Fig. 3 Rectified image of plane 2 of the western side (at scale 1:100)

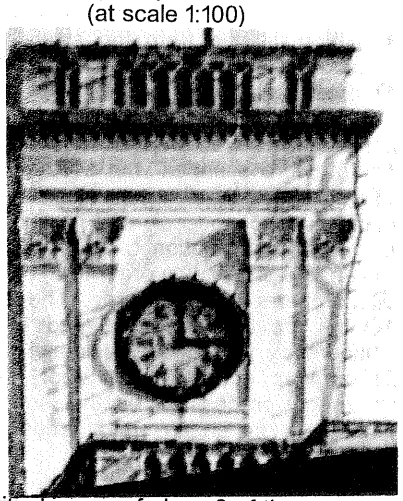
Fig. 4 Rectified image of plane 3 of the western side (at scale 1:100)

finding points of known coordinates, through the stereorestitution or by measuring on the old plans, which were at the same time recognisable on the photos. So, the rectification was done by following the method of "known directions in space". In this case, it should be determined:

- the position of the vanishing points, as intersection of bundles of lines having vetrical and horizontal directions (parallel in the object)
- the position of the principal point, by measuring the fidutial marks, or in the case they do not exist, as here, by knowing the ratio between one horizontal and one vertical distance. These distances are defined on the object and measured on the image.

The whole work was done by using two software packages, alternatively:

a. A S/W package was especially written in AutoLisp, in AutoCAD environment where the whole rectification is completed (image input in tif format). This S/W algorithm executes the calculations needed for:
   - the determination of the vanishing point coordinates, by using the equations of vertical and horizontal lines, that are parallel in the space and are defined by the digitization of their edges on the screen
   - the dermination of the rectification parameters, by using two perpenticular distances of known length, or in a more general case the ratio between an horizontal and a vertical length (the formula is broadly known and described in plenty photogrammetric papers, i.e. Barnard, 1982/ Novak, 1992)
   - the determination of the coordinates of the facade details, which belong to the particular plane and are

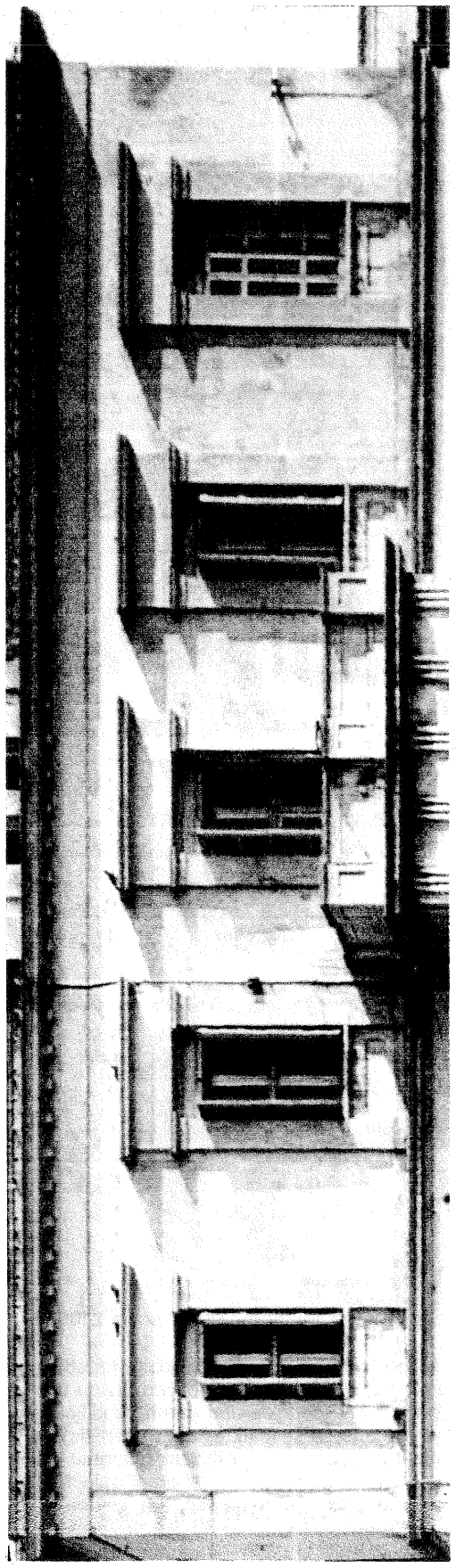

Fig. 5 Rectified image of the upper part of plane 1 of the western side

digitized on the screen, by using the rectification parameters
- the off-line production of the drawing on the screen, by using the coordinates calculated above together with their code numbers. So, the vector plans of each plane of the facades are created.

b. For the production of photomosaics and for the raster output of the rectified photos, the programme ARCHIS/V of Galileo Siscam, operating in Microsoft Windows (3.1 or later versions) environment was used. For the rectification there is a need of at least 10 Mb free space in the hard disk of the PC (at least 80386 with 4 Mb RAM). This programme can rectify a scanned image by using either control points or bundle of horizontal and vertical line observations. In the second case, which was used for this project, the algorithm is basicaly the same as before. The only difference is that the whole procedure and the rectification is accomplished by using the raster image and not the vectors of the digitized lines. The result is the creation of a rectified image of each plane of the facade, where can be achieved off-line:
   - photomosaic production, by determining a unique scale in all images of the mosaic
   - output of the rectified image or the photomosaic, in inkjet plotter or raster printer
   - vectorization of the raster information by using graphic tools (lines) and codes on the rectified image, and output in dxf format for further processing in a special graphic S/W package, i.e. AutoCAD.

The metric information used for the rectifications, such as length of horizontal distances and heigths of the facades, was derived:
- the lenghts of the sides which consist the outline of the building, from the existing topographic diagram of the area of the building (at a scale of 1:100)
- the window and door sizes and some other lenghts in the internal area of the rectification planes, from the two existing facade plans (at a scale 1:50)
- the heights of characteristic points of the building, mainly on its outline, and some horizontal distances in the internal area of the rectification planes, from the analytical stereorestitution (X, Y, Z coordinates of points).

On Fig. 2 the initial amateur picture of the western side of the building is given and on Fig. 3, 4 and 5 the rectifications (raster images) accomplished by the ARCHIS/V, of planes 2, 3 and 1, as they are marked on Fig. 2. Also, on Fig. 6 a photograph of the southern side of the building is given and on Fig. 7 the results of the rectified planes 2,1 and 3 (as they are marked on the initial picture) on a photomosaic at a scale of 1:100 are shown (only the parts belonging to the upper store).

The result of the rectifications in vector form was compared with the corresponding distances of the existing plans (the topographic diagram and the plans of the facades) and where necessary an adjustment was made. It was also compared with the internal dimensions of the building, that are shown on the existing three planimetric plans. In general, only a few deviations of 10-30 cm are found between distances photogrammetrically calculated and those derived from the old plans of the building, which allow the simple adjustment of all the data necessary for the creation of a uniform 3D model. After all, it must be mentioned that the existing old plans themselves, when compared with eachother (especially internal plans with facade plans or facade plans with the topographic diagram), had discrepancies of 5-15 cm at cetrain lenghts.

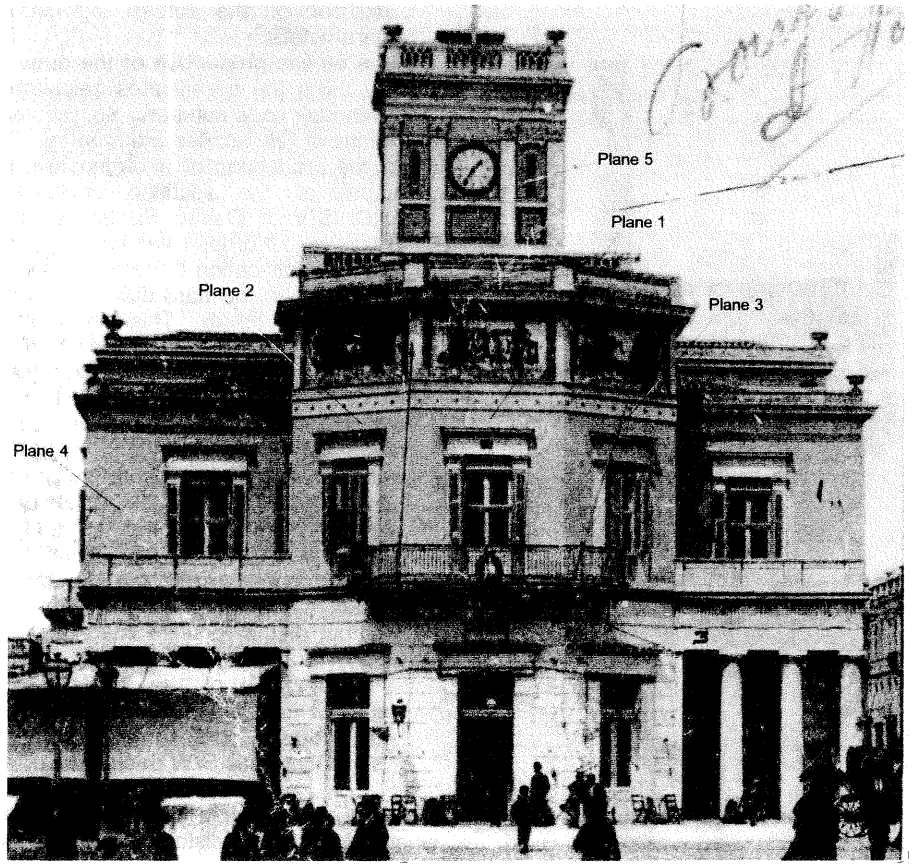

Fig. 6 Post-card of the southern side of the building

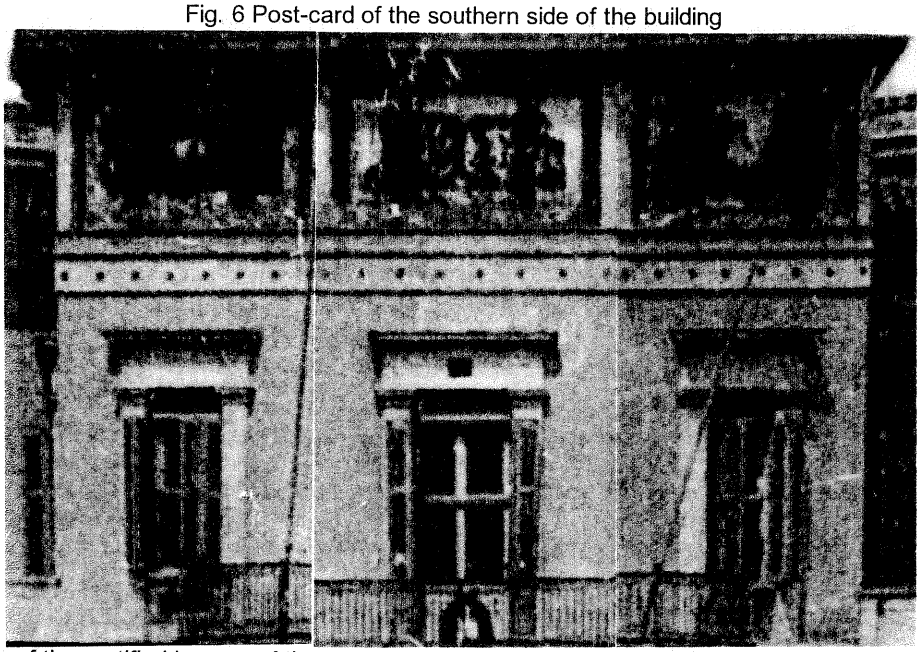

Fig. 7 Mosaic of the rectified images of the upper part of planes 2, 1 and 3 of the southern side (at scale 1:100)

4. CONSTRUCTION OF THE 3D MODEL

For a more efficient documentation of the building, a 3D model on the PC was made by joining the vector files together. This was achieved by special software written in AutoLisp, in AutoCAD S/W package environment, so that:

- the local coordinate systems, to which the rectifications of the sides are referred, to be adjusted together
- each detail point of the rectified facades, to acquire the correct third dimension automatically.

The size and the complexity of the building, together with the large number of rectifications produced, made the task extremely difficult. The detailed and careful codification of the data (per facade, rectification, characteristic) is the most fundamental factor for an efficient outcome (similar references are found in projects for different objects but of similar results, such as Heine, 1993). So, all the planes which constitute the building as a 3D figure in space and the characteristic details of each facade, as they had been restituted from the rectified photos, were created. Then, by

using the AutoCAD commands the necessary editing and the completion was made for

- the details which were not easily restituted on the rectified photos, i.e. decorative elements under the balconies or on the corners, cornices with a relief, rails etc
- the various planes and slopes of the ceilings and the remaining elements which exist on the roofs (i.e. chimney).

The result of all this effort was the 3D model production of the whole external figure of the building and the ability of producing the facade plans just by simply selecting the plane of each facade and projecting the stereomodel on a plane (X, Z) parallel to that particular facade. Also, the production of perspective plans from any point of view can be easily made. On Fig. 8 an output of such a plan which shows the southeastern side of the building from an angle of 22° above the horizon is given.

5. CONCLUSIONS

The application of simple digital photogrammetric techniques on amateur photos with no available information about the exposure conditions or control points, but only some elementary metric information concerning the object of interest, can possibly lead to the compilation of detailed plans, even to a 3D modelling of the object, with an acceptable accuracy, of course always dependant on a number of factors.

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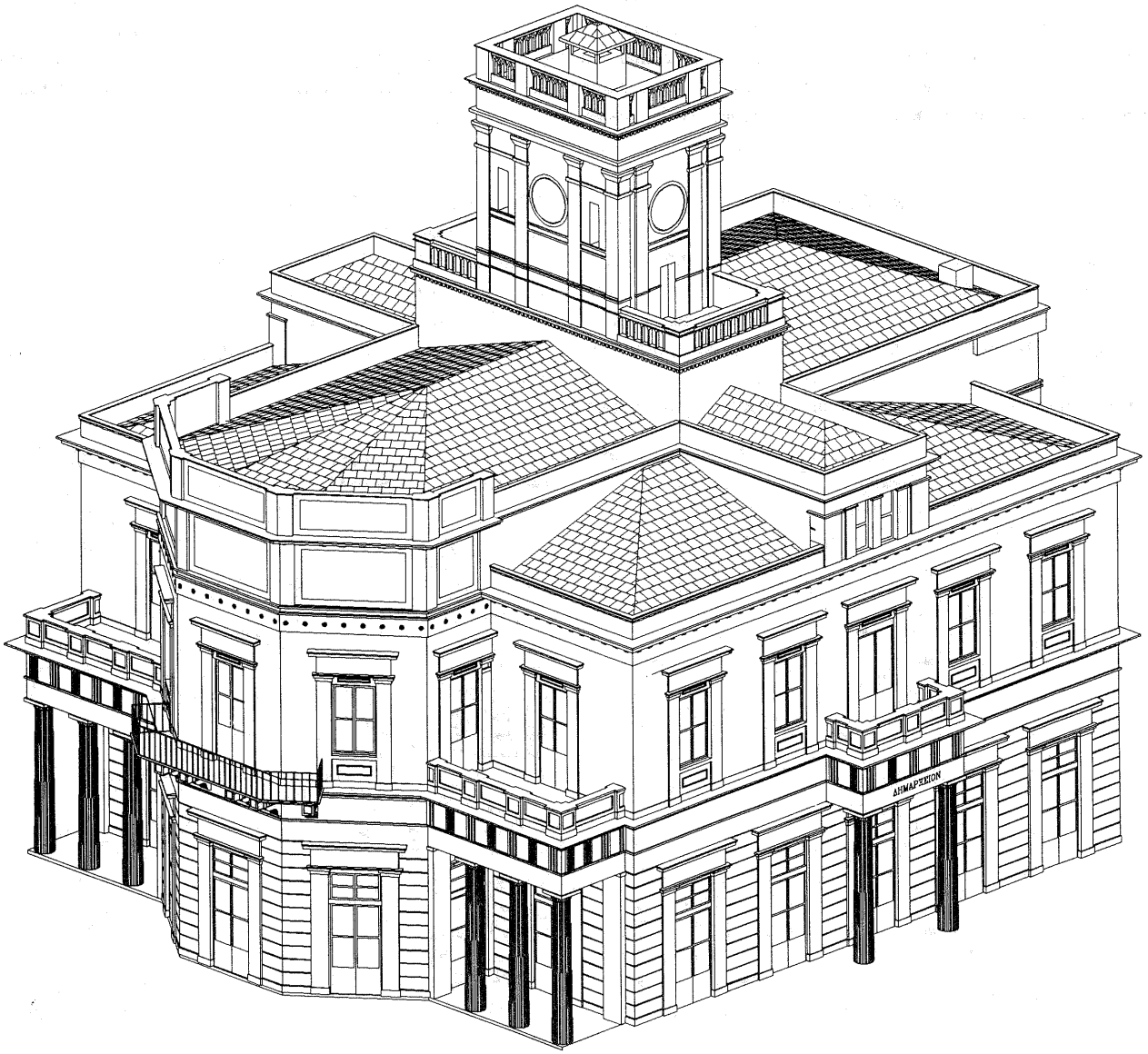

Fig. 8 Perspective view of the 3D model