4.2
From Image Space to Model Space and Back Again

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The paper describes in detail a process of work consisting of merging a virtual model into a real image. This process implies three different kinds of operations: geometric restoration of the real scene, in 3D, from a photograph, rendering a virtual model under similar conditions as the photograph, and merging of the rendered image with the original image. The paper empasises quality and visual precision of results together with a semiautomatization of the entire process. It also refers critically these three different groups of operations to their theoretical background. It concludes with an evaluation of the work from the point of view of architectural visual analysis and from the point of view of architectural visual analysis and from the point of view of a general design methodology.

Introduction

We would like to start this paper with a statement that may sound paradoxical: Technological development may stand in the way of scientific development. This statement sounds paradoxical because, obviously, technological development depends upon scientific development. But each technological innovation builds upon a series of previous advances that are taken for granted. In academic programs, a thorough explanation of previous steps is usually underrated or obviated, as a result of the difficulty of summarizing complex processes of no immediate interest. Social pressure demands quick results. For these reasons, the final product becomes out of reach for the non-specialist. So, in countries like Spain, with a scientific culture scarcely consolidated, technological innovation becomes chronically dependent on other regions and countries that count on more solid grounds.

The paper we are presenting does not contribute a very significant step towards better procedures in creating architectural models or images. But we believe that, not only do the results we have obtained have enough interest to show them in this academic fore but also the more importantly, that they sustain a methodology that tries to recover and redefine some fundamental concepts that form the groundwork of sophisticated techniques that now are starting to be popularised through various kind of commercial software. Because of this, we think it is worth starting with a brief summary of basic concepts implied in the process and that too often remain hidden by the refinements and complexities of technological products.

Theoretical background (1) : "Iconometrie", "Metrophotographie", "Photogrammetrie" and "Stereophotogrammetrie".

The first step in the general process of simulation that we are introducing, is the restoration of a real scene as it appears in a photograph. This is something that can be done at present by automatic means through stereometric photographic pairs but that can also be done by hand starting on a single copy. This second possibility meets with some drawbacks but it also has some advantages. The main drawbacks are: a) reference measures from the real scene are needed; b) there will be merely local control of the objects situated upon the reference plane: c) limited precision. The advantages are: a) minimum cost; b) independence from heavy and complex equipment; c) sufficient precision for some applications.

Taking into account the circumstances in which act the vast majority of researches and professional architects that work in this area, we should say immediately that the advantages are overwhelming superior to the disadvantages. However, these kind of procedures are scarcely known and scarcely used. We are confronted with a typical case of what was advanced above: the dramatic development of stereophotogrammetrie has made older techniques that could be more suitable for the majority of the current working conditions, obsolete and practically unknown. It may be of interest, because of this, to insert here a brief historical note.

The birth of photogrammetry is practically coincident, with the birth of photography. Current geometric and optical knowledge, at that time, the middle of the nineteenth century, made immediately clear that production of photographic images obeyed to objective laws and that this would allow, if had sufficient data, to restore the real scene that corresponded to a given image. The theoretical principles upon which photogrammetry was based were developed by Laussedat around 1850 using a *camera chiara,* a device invented by W H Wallanston in 1804. Laussedat named his technique "iconometrie" and it was applied initially to restorations based on drawings made with the help of the camera chiara and "fotogrametrie" when it was applied to images based upon photographs. The work of Laussedat was based itself, on other kind of works made years before, such as the restorations made by Beautemps-Beaupre en 1791 on the Pacific shore. They also derived from basic geometric operations to build "inverse perspectives" that have been determined by Taylor, at the beginning, and Lambert, at the middle of the XVIII century.

The techniques introduced by Laussedat came to be known, France and Germany, mainly through the Work of Maydenbauer "metrophotographie". At the beginning of our century, another French researcher, H Deneux, realised a lot of restoration works based on any kind of photographs, and published a book on metrophotographie, at 1930, that made better known this technique. However, during this same period, before and during the First World War, other researchers, Poivilliers among them, developed more sophisticated techniques that led to stereophotogrammetry. In 1934, in a convention that took place in Paris, there were big arguments between those who favoured the old techniques and those who favoured the new. After the war, stereophotogrammetry was applied continuously to cartography in a progressively more complex and refined way until it has become a ubiquitous way of creating maps and has also become a major procedure in architectural historical restoration.

So, we are confronted with a characteristic case of what was stated at the beginning of this paper. The development and the importance acquired by photogrammetry has obscured the application of basic techniques, that can be implemented in a much easier and simpler way and that are extremely favoured by the possibility of integrating them in a computer where some geometric operations that although were difficult and cumbersome by means of traditional techniques, become trivial and can be automatized without difficulty.

Theoretical Background (2): Architectural Rendering

The development of rendering techniques has reached a point where research and efforts of all kinds intended to obtain "better results" have become problematical. The main reason is that, starting on some specific level of technical development, a definitive criteria of what is a "better result" neither exists nor can exist, just as neither exists nor can exist a definitive criteria of what is a "realistic representation". This adds up to the fact that techniques available at the present time allow us to obtain acceptable results for the majority of cases, if they are used in an efficient way.

The present situation, that probably will be established for quite a long time is characterised itself by the use of 3 or 4 basic techniques that come together with a growing number of tricks and customized techniques a full command of which will be the key to obtain good images.

These 3 or 4 techniques are, in regard to local reflexion models, the empirical algorithms introduced by Phong 19 years ago, and the corrections, coming from a more solid ground, contributed by Cook and Torrance, among others, 12 years ago, that have been incorporated recently to popular software packets like 3DStudio v.3.0. In regard to global reflection models, the 2 basic techniques are ray tracing, introduced by Whitted, 14 years ago, that only 3 or 4 years have been available to personal computers, and radiosity, introduced by Goral, Torrance and Greenberg, among others, 10 years ago and that are still too expensive, in computing terms, for use in personal computers. The same can be said about mixed techniques of ray tracing and radiosity that appeared later.

The efficiency of these techniques depends directly on the context in which they are used. Thus, in the case we describe in this paper we would not have obtained any better result using techniques more refined than Phong's. Not even the Cook and Torrance model would have brought any noticeable improvement despite the fact that it is, in theory, "more suitable" to simulate the materials assigned to the model. Similar considerations could be made in relation with multiple cases that we cannot summarise here. Cases where, for instance, the use of ray tracing would not bring any substantial improvement compared with algorithms less consistent from a theoretical point of view, as environmental mapping, but much more economic in terms of computing time and facility of application.

What however becomes crucial is the capacity to evaluate the distinctive features of a scene that result from the interaction of light and objects, in such a way that it favours a proper judgement of the situation and, from this, a proper way of acting upon and stressing the key features while disregarding the secondary ones. An image is above all, a selection.

Theoretical Background (3): Architectural Image Processing

What is currently called Image Processing configures a wide area of research from which important contributions are to be expected in the years to come, in many different kind of applications including the architectural ones. In the particular frame of this paper we will refer to two subareas, vectorization and image retouching.

Transformation of images into drawings or, more exactly, of bitmaps into vectors, that is to say, geometric lines that can be edited or transformed into proper representation of forms, is an area of research from which substantial improvements can be expected. Improvements that will come from intelligent programs, sensitive to context, that will allow automatic simplifications, erasing of massive quantities of irrelevant information that in most cases, at present, must be eliminated by hand.

Image retouching by means of basic geometric operations performed upon pixels, in the extensive sense (translations, copies, rotations, change of scale) and basic operations performed on pixels in the intensive sense (colour modification, filtering, etc.) has quickly reached such a level and availability that it allows us to create virtual images that cannot be distinguished from photographs of real ones. This is accomplished by what should strictly speaking be called electronic craftsmanship. During the ECAADE Congress of Barcelona, 1992, we had the opportunity to present some samples of the work we have performed in the last few years to simulate and consequently evaluate the environmental visual impact of small urban projects in Spain. These images had considerable success among our clients as they satisfied the current idea of realism; that is, they could not be distinguished of actual photographs of the unmodified sites.

However, these types of results are limited. What is been modified are plane images, not forms. From the point of view of design practice, this limitation is quite important, despite the fact that it remains a means of work that should not be ignored.

In this paper we have practically disregarded direct retouching to put the stress on a process that wants to lean directly on form. We should say, however, that some degree of retouching is necessary if we want to remain close enough to a minimal level of visual quality. It is necessary, for instance, to soften the union of the two images if one wants to maintain the fidelity to visual detail nuances. These retouching is a necessity forced by the need of supporting what we consider visual quality minimum standards and can be considered as an impurity in the process. In any case, they are a time lag, an stop in a stream of routines that goes on with sufficient fluidity.

Description of a Case (Oteiza's Sculpture in front of Hilton Hotel at Barcelona)
In the last 2 years, and in the context of different kind of courses and projects, we have followed the same driving theme; a process that leads from a given image to a modified image through clearly defined phases. This process is described in detail in what follows on the basis of a particular case. We started on a hypothetical job which consisted on evaluating the possible effects of placing a sculpture on the pool situated in front of the Hilton Hotel in Barcelona, a piece of work designed by the architects Pinon and Viaplana in 1992. The sculpture was work by the Spanish sculptor Oteiza. The whole process can be done in 4 main phases:

1. Restoration of the real scene("scene 1") starting with a photograph of the site ("image 1");
2. Incorporation into this scene of the geometric model of the sculpture to produce a new scene, with a new object in it ("scene 2");
3. Incorporation into this scene of material characteristics of the new object, of illuminating conditions equivalent to those of the original scene and, lastly, visualization, from the same angle and distance of the original scene to produce, in this way, a new image ("image 2");
4. Merging of the new image and the original image to obtain, finally, the image that was looked for ("image 3").

Each of these phases is described in detail below.

4.1 From image 1 to scene 1 (3D geometric restoration from a photograph)

- Photographic Shot

Preliminary images were taken with a reflex camera, 20 mm lens, levelled tripod, focus at infinite, verticals controlled through the grid on the viewfinder. We also used a clinometer for an additional check of the levelling. Colour Kodak Ektar 100 ASA film 24x36 mm was used. The controls just mentioned were used to provide complementary control in order to evaluate the precision but are not required by the basic process.

Printing was made upon 10 x 15 cm colour copies. One of the images was selected as most adequate for the job. We shall call this image corresponding "image 1".

- Digitalization

The selected copy was digitalized with a Epson GT4000 scanner. Two records were made, one at 400 dpi with 256 gray steps (8 bits per pixel), starting on an amplified white and black copy, 18x24 cms. This produced a monochrome image of 2800 x 3400 pixels (width x height) and 9,6 kb size. The other record was taken at 144 dpi, true colour (24 bpp), starting on a colour copy, 10x15 cms. The first copy was used during the process of geometric restoration and the second copy during the final merging process.

- Vectorization

The monochrome bitmap was converted to vector data with the program Adobe Stream Line using the following options: 1) Converting method "noise level = 2", "centerline", 2) Tolerance "tight" (match bitmap:1.0), 3) Line Attributes in mode "straight lines only", 4) Colour Setup: 2 colours, maxim smoothing, contrast 10%. The converted file was saved in dxf format.

- Geometric extension of scene 1.

The converted file was taken to AutoCad where polilines were exploded to reduce their width to 0, the drawing was rotated to adjust verticality, main lines of the image were selected and, starting on them, the general perspective was recovered with main vanishing planes incorporated to the drawing as it is shown in Figure 1. We will call this scene, corresponding to image 1 "scene 1".

To fix the point of view, independently of photographic shot conditions, measures were taken on two parts of the original image. Starting from these data the point of view coordinates were obtained at the intersection of the two arcs corresponding to the angles of the triangle formed by the two known segments as it is shown in Figure 2.

From Scene 1 to Scene 2 (Insertion of the Sculpture and Geometric Modelling of Scene 2)

The geometric modelling of Oteiza's sculpture was inserted in scene 1, with an overall size of 180 cms at the position indicated in Figure 3, upon the pool's main axis.

The sculpture was situated 10 cms above the water plane and, below, an inverted copy of the same was created, 10 cms under the water plane. Camera and target position were indicated by two planes forming a "v" pointing to one another, with the vertex at x,y and major length equal to z.

From Scene 2 to Image 2 (Rendering of Scene 2)

Scene 2 was exported to 3DStudio. In 3DStudio the camera and target were located at the positions indicated by the two planes mentioned above. Two pairs of "spot" lights were created, pointing to the sculpture main planes, each pair excluding the symmetrical object. Lower lights, pointing to the reflected object, were assigned an intensity 30% lesser than the upper ones. Both pair of lights were positioned close to the objects they were aimed at. Attenuation ranges were adjusted in such a way that interior planes were left almost at darkness. The general idea was to cast an overall luminosity on visible planes and to force contrast between exterior and interior planes.

Simple and bright materials were assigned to the pool edges and control points to have a suitable reference during merging. The material assigned to the sculpture was based on a bitmap obtained by a photograph of yellowish sand, inserted at 100%, with modified colour to carry it to a band of oxidized red hues ("lumatint" in 70,0,0 y 200,60,20). It may seem bizarre to model cast-oxidized iron with sand but we found that this provided a better look than bitmaps based on photographs of actual oxidized iron.

The rendering process was carried out with antialiasing parameters medium values to create an image 1024x768 pixels in TGA format.

Merging of Image 1 and Image 2

We arrive, in this way, to get two images, "image1" and "image2", situated in a projective space of equivalent proportions.

Image 1 and image 2 were recovered from the program Aldus PhotoStyler v.2.0. Screen coordinates of two homologous reference points were taken in order to normalize the size of the two images. Image 2 size was changed, multiplying the horizontal number of pixels by a reduction factor and resampling the whole image in this way to get the homologous points that had to be situated at the same screen coordinates. This can give results too approximated if control points are not used through the whole process.

Technical Considerations

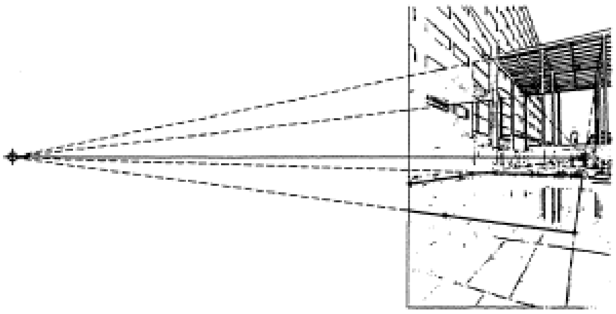
One of the aims of the job has been to consolidate the routines, in order to get them applied in a semiautomatic way, and as quickly as possible. There are some variants that deserve comment as they would facilitate and speed up the whole process at the price of less geometric precision. For instance, if one accepts a resolution limit on the starting image around 950 pixels maximum, it is not necessary to vectorize the bitmap. It can be traced over directly in AutoCad using the command Render/Replay Image, and the main lines (silhouette, vanishing points, control points, etc.) can be fixed directly on top of the bitmap, with an appropriate colour and on an appropriate layer.

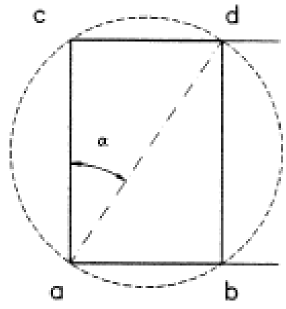
In any case, the whole basic restoration process of the scene can be accomplished in a working session of about 2 or 3 hours maximum and the whole process in a day. The moments in which a more elaborate decision must be made are mainly two. One related with lights and material assignment on the model to be inserted and, secondly, the one related with the merging process of the images and the unavoidable retouches to be made on the result.

Non-technical Considerations

The production of photorealistic images in architectures is sometimes rejected as it is considered that they may imply a concession to show effects at the expenses of conceptual elaboration. Without rejecting this possible criticism, we consider that they should continue being a fundamental area of study for a reason over all. The production of these types of images fixes the measure by which we are able to control visual attributes that are an essential part of architecture. Since antiquity these attributes summed up in two principal descriptive categories: Colour and Form. Colour is a one-sense attribute; no other sense knows it; it is, to visual arts, what sound is to music, the primary matter from which one starts. Form is a many-senses attribute; it is common to every sense. None of these categories mean anything in the absence of the others: we do not perceive colour or sound without form. Neither do we perceive form but as visual, auditive or tactile structure. And not any of these primary descriptive categories can function without a third one: intention and significance that place colour and form in a meaningful context.

Colour, Form and Meaning are the big words that allow us to analyse architectural images. They configure an order that goes from the most pure to the most complex. Colour is the most simple and, apparently, the most trivial. It seems to be little more than the initial condition that allows the

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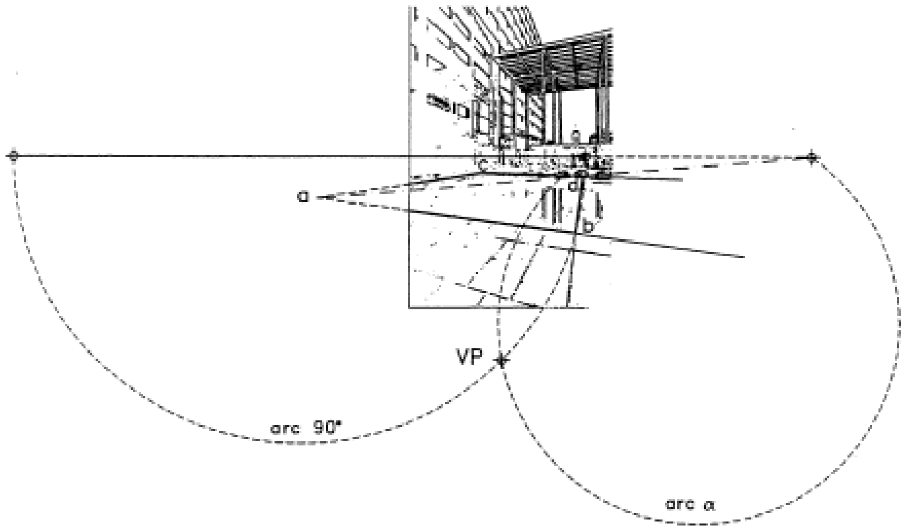
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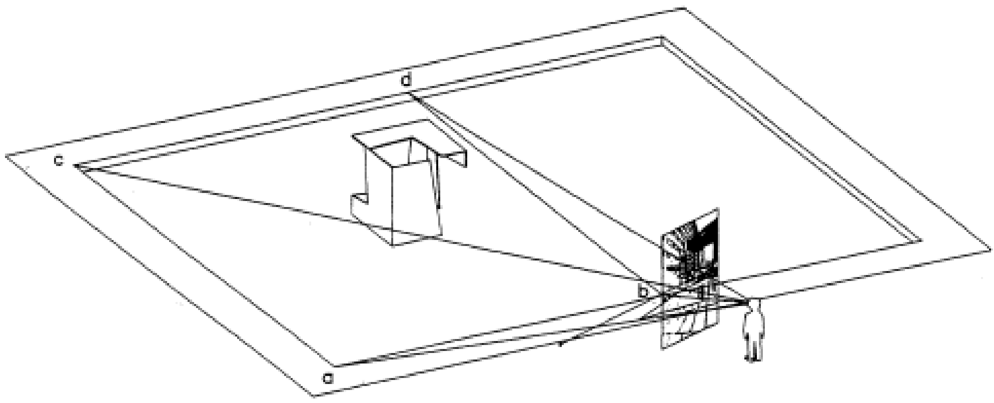
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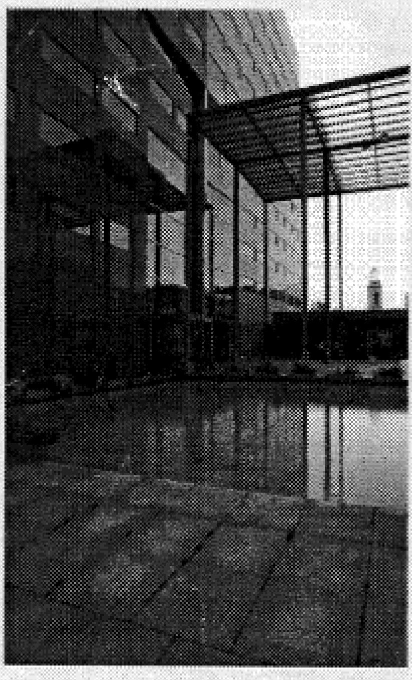

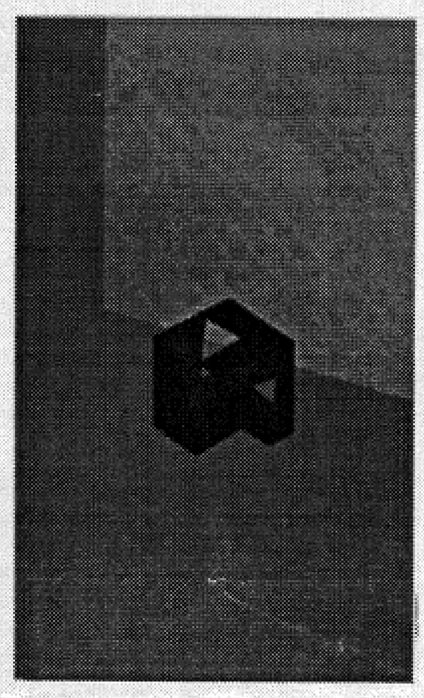

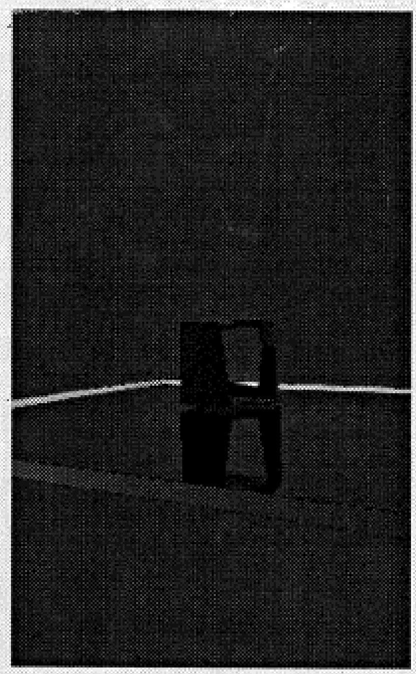

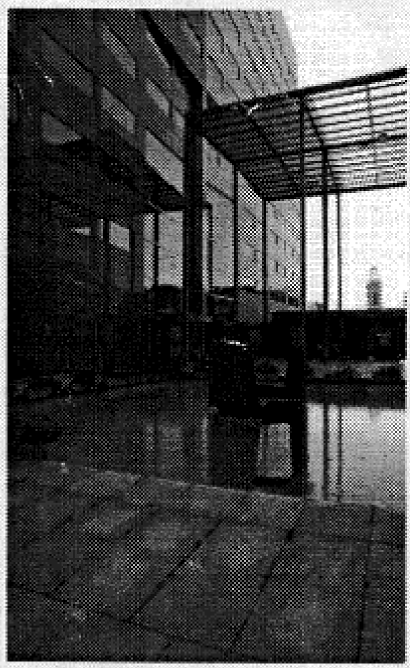

emergence of the other two categories. But only a proper understanding of the colour order and chromatic interaction will allow us to have control upon form in the case of complex images where many different forms are related and mixed between them. This cannot be doubt as soon as we abandon the analysis of isolated objects and focus our attention towards a real situation, a real context, a natural landscape or an urban landscape. This key work "landscape" where colour, form and meaning come together, give us the measure of the extent in which, too often, a proper control of colour is overlooked and its key role as a preliminary condition to master form, and the meaning of form, is ignored.

The paper we are presenting must be understood in the general context of a particular position that tries to recover the value of a strict visual analysis grounded on the command of tools capable of producing and reproducing images, as an essential condition of architects current activity. This kind of knowledge and command was taken for granted in classic education and has been partly disregarded in modern education. The development of computer technology has been used sometimes as an excuse to talk about the obsolescence of some representation techniques. Our opinion is that they should be regarded in exactly the opposite sense; as an additional proof of the significance of visual analysis and as a way of reinforcement of this kind of analysis.