Filmic Development of Architectural Animations
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This paper proposes a general method to make animated presentations of architectural designs, based on cinematographic techniques. Particularly, it reviews theoretical documentation about filmmaking as well as several productions that exhibit remarkable locations. The proposed method first comprises of a planning stage, with the narrative and graphic formulation of the presentation. Next is an elaboration or adjustment stage for the digital modelling of the design, and finally, there is an animation production and editing stage. Likewise, the research sets up a computer implementation of some activities and characteristics, and experiments in the programming of camera movements for architectural animations. In general, this work suggests focusing on the communication of the qualitative features of the design, instead of the elaboration of the digital model, and on emphasizing the visual diversity, graphic style and narrative construction of the presentation.
1. Introduction

Animations are a relatively new resource for architectural representation that have mainly arise due to the capability of moving the camera in digital models of projects, making possible to dynamically display volumes. But in general, there is a lack of professional experience about moving exhibitions, while software tools are targeted to generic use without specific aids for architectural visualizations. Because of this reason, animated presentations of buildings are usually long and boring tours through sophisticated models. Some authors have commented about certain movies and filmic principles likely to contribute in architectural exhibitions [1–5]. However, the examples and characteristics analyzed are few and they are not related to the animation development process.

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Theoretical texts about filmmaking [like refs. 6–8] give a broad overview of cinematographic concepts, while some documents about digital animation [9–10] intend to apply some of these principles in the new digital technologies. However both types of references focus on how to show characters and not buildings. Hence, in order to identify filmmaking techniques for displaying architectural environments, we pursued a detailed study of several films distinguished by their settings, some documentaries of historic constructions, and various awarded architectural animations [11–12]. The selected movies were also chosen to correspond to intervals of approximately 15 years, in order to map the chronological development of cinema: “Intolerance” (D.K. Griffith, 1916), “Metropolis” (F. Lang, 1927), “Citizen Kane” (O. Welles, 1941), “Mon Oncle” (J. Tati, 1958), “2001: A Space Odyssey” (S. Kubrick, 1968), “Bladerunner” (R. Scott, 1982), “Total Recall” (P. Verhoeven, 1990) and “Episode II-Attack of the Clones” (G. Lucas, 2002). In each movie, a scene that introduces a relevant place for the first time was studied. Documentaries were chosen among collections of cultural videos and selected for displaying particular landmarks such as: Ville Savoye of Le Corbusier (BBC, 1972), Saint Marc Basilica in Venice (Bauerischer, 1980).
Church in Hokkaido of Tadao Ando (M. Blackwood, 1989), Eastern Palace in Madrid (Agostini, 1992), Royal Castle in Prague (F. Verlag, 1992) and Robie House of F. Ll. Wright (Ed. Planeta, 1994). Finally, the animations were chosen among productions that received recognition at some international competitions (Autodessys, COAC and Siggraph); Republic Pavilion of J.L. Sert (Soft, 1992), Speedway Center (S. James, 1997), Urban Residence (T. Maeda, 1998), Insurance Building of F. Ll. Wright (DiSimone, Kosinski and Frampton, 1998), Rockbridge Cristian Church (Llonch and Vidalle, 2002) and “Cathedral” (Platige, 2002).

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The study identified the different views that compose the sequence, capturing one frame (or several when there were camera movements) of each view, in order to analyze the image setting, the development of shots and the presentation montage. We also collected documentation about the production, environments and buildings showed, elaborating digital plans of the places and estimating the location of the different point-of-views (through perspective restitution of the frames). This process allowed us to...
recognize the position, visual angle and inclination of cameras as well as calculation of trajectories and velocities of movements. In addition, the study reviewed the graphic principles applied in the images (symmetry, guides, hierarchy, scale, depth-of-field, etc.), the distribution of views and durations, and the narrative development of the sequence.

In order to transfer the knowledge gained from this film study to the making of animated presentations of architectural designs, we have developed a method that takes the most relevant cinematographic procedures and adapt them to existing computer systems capabilities. Although filmmaking principles are mostly devoted to long fictional productions, some working conditions and possibilities can encourage the creative elaboration of animated presentations as an effective way to
communicate architectural designs.

The proposed method is composed of three main phases: (1) presentation planning, (2) elaboration or adjustment of digital modelling, and (3) animation production. Finally, we propose a digital implementation of this method, experimented in a script for camera movements in architectural animations.

2. Planning

Cinematographic productions usually have a clear entertainment purpose, filtered of course by commercial and artistic interests. Meanwhile, a variety of competing influences enlightens the production of animated presentations of architectural projects. Sometimes, animation tries to complement the conventional information of design, through short moving views. On the other hand, there are instances when the animation is expected to summarize the whole project. Furthermore, certain presentations are made to explain specific characteristics of a design to a given audience, while others are used to persuade the purchase or use of a building, or to express the capabilities of the digital model, the working team and/or the client. Additionally, productive conditions may be different. A visualization work may be made in house during the design process, outsourced after that, or a combination of the two. Then, animation authors must coordinate their intentions accordingly to the available equipment, time, budget and data, focusing the aim of the presentation.
Since animations are time-dependent; there is a fundamental need to define the narrative development as suggested by several authors [1, 4, 5]. This can be set forth as a brief movie-script, taking advantage of the linearity and abstraction of text, with references to the visual sequence. For example the cinematographic scenes studied usually develop a scalar order. They begin with a “situation shot” showing the whole place. Then, there are the “intermediate shots” to show the characters or parts, and finally “close-ups” displaying faces or details. They proceed showing outdoor parts first and then the indoors. In some cases this order is reversed, starting in details and finishing with the whole building (discovering at the end the general situation).

The visual progression gets complemented by means of additional information about the temporal and geographical location, as well as its making, expanding the depiction but using different resources such as texts, pictures or sounds. Another technique employed is the progressive emphasis given to a qualitative topic using subtle graphic techniques (fixed views, chromatic effects, lightning). This content is gradually revealed, similarly to the main meaning of the scene. It is usually related to some previous situation or existing assumptions in order to stimulate the interpretation of the spectator.

After the verbal description of the narrative, cinematographic productions usually make use of graphic displays known as storyboards. In short productions they are flexible pre-production illustrations, such as freehand sketches and schematic plans that attempt to define the graphic style and meaningful point-of-views. For example, the storyboards for scenes of “Birds” and “Gladiator” show the change of views and different image treatment, while an illustration for “Tucker” also shows the different camera positions (Fig. 3). This kind of preparation in architectural animations can be helpful for establishing and reviewing the image setting, visual

![Figure 3. Storyboards for “Birds” (1963), “Tucker” (1988), and “Gladiator” (2001)](image)
courses, and collaborative opportunities in the modeling and control of details, appearances, and lighting.

In addition to preparing for the presentation, test-animations are highly advisable before engaging the main part of the job [2, 4]. Whenever possible, sequences should be preliminarily edited to allow for the narrative evaluation by the clients or audiences, which permit the refinement of the presentation’s effectiveness and requirements.

3. Modelling

Making the digital animation of an architectural project requires having a 3D computer model. Although nowadays it is increasingly common to develop volumetric representations of the design in the computer, there is likely to be the need for a further adaptation of the model(s) to assure an adequate presentation. As in a movie production, shooting locations must be selected and adapted.

Modelling can also suggest certain conditions of the presentation. For example, some elements that are too complex to elaborate and also lack design importance in the design (such as minor structures, topographic details or vegetation) can encourage the adjustment of the view settings or changes in shots to reduce its visual participation. On the contrary, some elements or effects that are easier to perform (e.g., repetitive components) can mostly be included in the presentation and encourage new views. However, none of these conditions should define the total visualization (which usually happens when the animation is mainly devoted to promote the graphic work), but instead, digital modelling should be subservient to the intentions and expressive demands of the narrative.

The use of prepared elements from libraries (such as windows, doors, staircases, trees, etc.) is an important aid to modelling, but a usually source...
of time-consuming in the rendering phase due the complexity and amount of shapes. This subject, is not so relevant regarding when rendering fixed views, but is very important in the case of animated productions visualization when rendering delays turn out to be critical. It is therefore recommended to prepare a database of objects specifically selected and adapted for this type of need.

The use of moving elements is also a frequent filmic resource to give dynamism in the exhibit show and maintain visual attention in shots without camera movements. Therefore, care should be taken regarding its participation in the image setting and its relationship with other shots, using movements with opposite directions to provide diversity in the sequence. Since architectural elements are usually static, and movements can only be showed opening doors, windows, elevators or sliding panels, by defining either transfers displacements (key positions in different frames of the sequence) or rotation ones (by functions and pivots). Sometimes the additional moving objects are included (e.g., vehicles or the mounting of building components), but these normally distract unless they have a meaningful role in the presentation. Even some casual movements such as TV-screens, fireplaces, or clouds (applied as animated textures), excessively call the attention to themselves, so they should be carefully used employed.

The use of people has been widely recommended because, in addition to give atmosphere and scale, they suggest the possibilities of occupation in the spaces. However, most of the resources enabling the inclusion of people are complex and distractive, due to the fact that they are devoted to the animation of 3D characters. A satisfactory procedure in architectural models has been to film regular people and incorporate them to digital models [13], which can also be extended to animals, vegetation, water, etc., taking care of their proper dimensioning and position, and a
variety that meets the project’s expected functions and audience. The mapping of images on surfaces (e.g., textures, materials) for animation purposes also requires care attention, because of its associated attributes, such as bumpy, transparencies and reflections, which delay their graphic processing. So, they should be used on elements with an important participation on visualization, while other less relevant (or distant) objects may be treated with plain colors or simpler textures. Besides, some building materials with grids (such as floors, tiles, shingles, or brickworks) produce graphic blurring in moving images. So, it is better to use more homogeneous finishing. Background images in the model also demand particular attention in animations, because visual displacements movements show their immobility. Therefore, colors or gradients have to be used or such images must be applied to cylinders or semi-spheres around the entire model.

Although lighting is also an important consideration an essential component in filmmaking, while in architectural animations have too often made a poor use of this resource by assuming a safe lighting has usually been used in a homogenous way homogeneity or just assuming the search of a supporting realistic representations. Cinematographic productions use lighting to stress the visual understanding of places and elements (giving depth-field), but also to emphasize the expressive nature of the situation. In movies the volumetric configuration of objects and spaces usually is enhanced through enhanced through three main types of lighting sources: “key-lights” to provide main illumination and lateral shadows, “fill-lights” to provide soft illumination to compensate for those darker sides, and “back-lights” (which are behind objects) to highlight the profiles. In digital models the intensities and other properties of lights need obviously to be adjusted in order to get natural lighting and proper rendering time, in particular by calculations of shadows and different algorithms of graphic processing.

Finally, the utilization of the wide array of visual means should also give rise to attain a graphic style that gives a particular character to the presentation itself (or the project or the teamwork), as suggested by Font [14]. Such style has to be reflected in a chromatic range, with elements and treatments that meet the narrative intentions of the animation and the author’s creativity.

Despite being obvious, we should add that successful production requires diligent file organization and accessibility. Digital modeling involves a complex structure of digital files, made up by geometric information in progress, libraries of objects, textures, backgrounds, images and videos generated for production, interactive models, etc. All of them should be kept clearly organized and accessible for teamwork. This is essential for taking full advantage of the work produced and in progress demands the creation of a clear system of operation management, particularly when the production team is composed of many individuals.
4. Production

The most remarkable aspect identified in the cinematographic productions analyzed was the variety of shots used to show places and buildings, all of them achieved with brief and simple camera movements. A dozen of different views illustrate each location, some of them are fixed and others with reduced and regular movement. In contrast, architectural animations frequently use a long trajectories trajectory trying to give a complete geometric description of the entire building. Besides, in the sequences studied most shots are partial and targeted to opposite directions (instead of wide and central images as in the case of conventional architectural images), thus encouraging a fragmented presentation and a mental construction of spatial situation. This strategy implies the arrangement of several cameras in the digital model to produce different views and short animations.

The filmic scenes also reveals shots concentrated in certain sides of the building and some few rooms (or only one), keeping a general order from exterior to interior views, apparently to get an easy spatial understanding and global orientation that balances the graphic diversity. Displaying similar elements from different positions, such gives continuity and variety. However, it requires special care of the visual composition. This visual distribution of filmic scenes does not help much to display the overall place, but allow an intensive communication of its spatial conditions.

According to the studied examples, it is advisable to define some general conditions for every view, such as size and proportion of image (preferable with panoramic formats to concentrate the visual focus on the central part), as well as the duration and frequency of animations. The format of digital files, compression resources and rendering capabilities also should also be carefully considered and planned as they condition the storage and
processing time. Since these requirements could be crucial in the
distribution or last final production steps and distribution phases, they can
define previously the particular characteristics of the image and animations.
The cinematographic documentation [6–8] suggests that each view should
facilitate visual legibility and provide graphic interest. Some elements can be
emphasized through contrast, lighting, size, shape, color or movement.
Creating several focus of attention in the image, with visual balance that is
usually asymmetric, compensates diversity between shots. Furthermore,
maintaining a homogenous direction of shapes in the image facilitates an
easy understanding. There are times in which the views are composed with
the support of reference guides, like thirds of the frame, to distribute
graphic elements and to compensate the visual weight on the left side and
bottom sides. In addition to this, filmmakers emphasize depth-of-field through
lightning, blurring elements or camera slanting, and use different heights and
distances to the objects being filmed (like a “scale of shots”). The visual angle
(called field-of-view in several modeling software) also can be changed
among shots, but it is advisable to keep a value close to normal views at
regular exhibit viewing distances (next to 48º), in particular to avoid spatial
distortions in camera movements. The different shots of the studied
productions studied have varied durations, ranging from 4 to 40 seconds,
(probably to assure minimal understanding in the shortest time period,
while until keeping the viewer’s interest in the longest ones). The camera
movements are not related to longused in short or long shots durations,
including rotations (called “panoramic” in horizontal turns and “tilts” in
vertical), or going around in different directions (called “traveling” if carried
out laterally to the line of sight, or “dolies” if done as in frontal
movements). Besides, the film sequences show the use of similar speeds in
camera movements (although the texts about filmmaking does not suggest
velocities). Movements feature slower values when compared to regular
animations, apparently to get a proper graphic spatial understanding.
Rotations of camera, frequent in movies to show spaces, have an average
angular velocity of 8 degrees per second with an extension of around 42
degrees (less than full image), usually relating two facades or sides of one
room, with close positions of the camera and following the horizontal or
vertical direction shape of the elements exhibited. Pedestrian height
movements show a regular speed of 1.2 meters per second (similar to a
walk), and aerial views ranging from 7 to 15 meter/per second. In both
cases the movements have reduced trajectories of about one-sixth of the
building length in outdoors, or one-third of indoor spaces, usually using
ample curves and slanted visual direction. This is very different from the
long trajectories and fixed views that normally characterize architectural
animations. In order to apply the values mentioned to digital presentations,
the velocities must be converted to frames at the corresponding frequency
of animation, and the length of trajectory can be computed by the ratio of
speed to the frequency multiplied by the duration expected (L = v/(f * t)).
The camera movements also showed particular arrangements in relation to buildings or rooms (Fig. 7). For example, in some outdoor settings, the camera usually develops an orbital or helix trajectory, with regular or reducing height, but most frequently just with partial movements, such as arcs in corners turning in different directions with the building centered. Long lateral pans, showing neighboring areas and short downwards movements are commonly used in cinematography. However, those movements never cross the entrance, because in film sequences the camera goes directly into the rooms. In the case of indoors, slanted frontal movements, curved lateral movements trajectories (travellings) or short right straight trajectories tours (dollys), and some horizontal and vertical pans are often found. Likewise, some moving shots feature architectural details in short pans or frontal viewpoints.

The average architecture presentation in the studied productions lasts about three minutes, which looks a proper duration to keep attention and communicate some characteristics of the place. The shots usually have diverse durations (called “metric” in filmmaking). For example, there are series of brief shots that are regularly differentiated and provide rhythm to the presentation, while longer shots in the middle part of the presentation are utilized to emphasize some special aspects. View sequences are usually ordered by the enclosure (first outdoors, then indoors), and compose by pairs of opposing directions (called “field-counterfield” in movies).

The arrangement of durations can be regulated in the editing process of animation. Editing also permits the use of graphic transitions among shots, although movies mostly use direct cuts to highlight variety. Although film sequences also may change formal directions, slanting views and compositions among shots, they keep the continuity through common elements, similar colors, and graphic conditions during the show. Besides, they can incorporate titles (small and dispersed in the presentation) and sound (e.g., music, speeches or noises). Even though architectural information is mostly visual, the use of sounds in moving images has a strong participation in communication impact. It is therefore recommended to include and regulate an acoustic record in the presentation. Sound may be employed to support narrative continuity fashion between shots, improve the overall production effect, emphasize some concepts and/or
partially differ from the ongoing visual information to encourage an integrated interpretation. Editing must follow not only the narrative plan but also incorporate creative occasions found in the making process.

Rendering animations in the modeling software and the full presentation in the editing software depends on hardware and additional resources (e.g., rendering engines, video boards, etc.). These capabilities determine work to meet deadlines and graphic expectations of the production. Regular work on animation regarding this task requires special equipment, network arrangements, out-sourcing services, or rendering-farms. Digital video formats and compression resources (codecs) should contribute to produce animation with as short processing time and as little digital storage as possible. The exhibition of architectural animations can be performed through various methods nowadays. For instance, ‘light-weight’ videos may be used for web sites or multimedia material and use small formats, contrasted images, brief durations and universal formats.

5. Implementation

Some features of the suggested method to develop architectural animations can be implemented in digital systems. In order to make the best use of today’s highly capable software, some conditions may be programmed or prepared to facilitate the job, although the imaginative formulation of the exhibition must also be taken into account. For instance, there are have already been several already experiences with programming camera movements started by Drucker [15]. However, they are mainly designed for following virtual characters for in video-games. There is also a proposal for interactive visualization of architectural environments [16] and a system to plan the filming of a building [15], but both of them have different aims. This article proposes an implementation for developing animated presentations of architectural designs based on cinematographic insight, which is used to design and program the edition process and configuration of the necessary animated cameras.

![Figure 8: Trajectories of camera movements in arcs around the building or going straight in a room.](image)
An example of our approach was developed with off-the-shelf modeling and animation software (3DS-Max). In this work, geometric conditions of camera movements were previously set up, with locations and trajectories of camera proportional to the general dimension of the building (Fig. 8). This means to define reference volumes in the digital model in regards to the building’s outdoor, indoor or particular detail. The purpose is to encourage a variety of views in the presentation. In addition, the particular graphic properties and rendering options are programmed to facilitate testing with some ease and then generate the visualization. These resources are programmed in a script that offers in rollout menus over the modeling window, with additional panels for the images and procedures. Likewise, the script can produce interactive models (in VRML) where the animated cameras are used like initial point-of-views with different locations and animated programmed displacements tours to support the understanding of the place.

The general system setup planned regards also considers resources to support (1) the management of geometric information and libraries of modeling objects, and (2) programmed procedures for moving elements, mapping textures, incorporating light sources, and rendering alternatives. Likewise, the system includes a method to manage the editing process, involving the preparation of a written proposal and a storyboard with...
rendered images of the model and test animations. Furthermore, the system permits the selection of templates for titles and libraries of music and sounds for architectural environments, all these integrated in digital video software for producing the final presentation.

6. Conclusions

Based on the success of cinematography at communicating spatial situations, we conducted a study of the techniques used to attain such feat. We have encoded the insights of such analysis in recommendations to improve architectural animations’ the production.

One general lesson is that the efforts should be focused mainly on the development of the presentation itself, instead of the elaboration of the digital model. Moving exhibitions of buildings must regard the communication of design features as their main productive goal, overcoming the strong bias to geometric construction and realistic appearances that unfortunately consume most efforts of the work in current presentations.

Additionally, we suggest the use of a variety of graphic resources such as diversity of views, image composition, different camera movements, and editing conditions, instead of the visual continuity, which is generally the main characteristic of architectural animations today. Furthermore, we encourage the balance of interest and stability in the visualization, while aiming at communicating architectural properties with a narrative development and formal style.

Our work also suggests a much wider expressiveness of animated presentations of building projects than a simple geometrical description. Animations ought to transmit spatial qualities, constructive characteristics, functional capabilities, urban conditions, social achievements, etc. This would enable focusing on the particular contributions of the design and project’s essential issues, thus getting closer to living situation conditions and the more transcendental values of architecture. Moving images can develop the simulation of a spatial experience through not only optical extension, but also – and mostly – through visual diversity related to features and meanings of places. Because perception is an integrated mental construction and based on non-linear processing that integrates knowledge and feelings, architectural animations should provide a variety of contents and makes up the fact that moving images in particular involve an emotional understanding that goes beyond objective visual information.

Moving images stimulate volumetric perception through parallax motion parallax, but also the visual interest and intuitive search for meanings, delaying the logical reading. As such they must supply orientation and develop a sensitive discourse that incites spectators’ memories and expectations. Animated representations must convey more than the geometry of the project, the vital yet elusive qualitative features of a spatial situation.
Finally, a partially explored computer implementation has been proposed, in order to facilitate the elaboration of architectural animations and encourage software adaptation. An evaluation of the suggested method will be done through the development of presentations for real-state marketing and historical preservation cases. This research may also be extended to the conceptual stage of a project, by enabling the generation and study of animated forms, be they for architectural, urban or industrial design purposes. It is also feasible to consider its integration to multimedia systems, interactive models, full-scale installations and collaborative work, in order to facilitate communication and experiential understanding among diverse people, cultures and technologies.

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References


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