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# Designing Intradiegetic and Extradiegetic Spaces for Virtual Reality

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*Fictions for virtual reality are mostly conceived either in an entirely virtual environment or in a real environment with very little transformation. It is infinitely rare to find examples of sets designed and built specifically for a 360° experience. Building, rather than remaining purely virtual, raises complex questions about the organization of a "space to play" and therefore how to produce a narrative for immersion and create a 360° film grammar. We thus have created a first 360° set for the famous director Marc Caro, for whom the question of off-screen raised a very complex technical problem regarding lighting, visual effects, staging, blocking and acting. In this contribution we will show how this was solved and why the definition of a 360° narrative grammar is crucial. These are important intricacies that place the user-spectator in the optimal conditions to appreciate the experience.*

**Keywords:** 360° cinema, Virtual Reality, Methodology and pedagogy, narrative grammar, Set construction, Isovist 3D

## INTRODUCTION

Announced several years ago, the generalization of Virtual Reality and 360° films in our image consumption habits is only being realized very gradually. The constraint of owning specific equipment coupled with a still uncomfortable practice hinders the massive adoption of 360° content in the leisure field. However, the year 2020 may be the year of the long-awaited breakthrough if the consequences of the pandemic allow it. The availability of user-friendly equipment such as the Oculus Quest or the HTC Cosmos and the multiplication of camera models, some at very attractive prices, could boost the market. Nonetheless, the production of content is abundant and the many festivals around the world are distinguishing works of exceptional quality that radically

renew our relationship with filmed narrative. The creation of 360° content infuses the field of research, but little in schools, be it cinema, art or architecture. Like a little more than a century ago, when cinema established itself in the landscape of artistic production, know-how precedes theoretical knowledge, action produces reflection, example guides theoretical construction, the multiplication of propositions allows us to discern constants.

For us, who introduced 360° narration at the Ecole Nationale Supérieure d'Architecture in Nantes 20 years ago through interactive 3D universes designed in WRML, the technical stakes of immersive tools have been confronted with almost ethical issues of redefining prerogatives for architects. The resistance of the professional world, reflected in the



Figure 1  
360 view from the set. Sets for 360° films are extremely rare. The construction of a real set helps to understand issues and solutions for a virtual reality experience. Photo M. Kolchesky

pedagogy of schools and more generally in schools of architecture, has paradoxically given our studio an *avant-garde* and innovative aura that pushes us to an even deeper exploration of a 360° narrative grammar.

We made the bet very early on that animated and then interactive digital images would become essential tools for architects. We anticipated software developments and monitored what was going on in the world of video games in order to catch a glimpse of the graphical improvements of the rendering engines. Cinema is also a constant reference. Although our students are big consumers of film images, whether from a movie or a series, few of them know the fundamentals of writing for the screen and how one can, without talking, depict a situation, portray a character, anchor a story in a space and time. The construction of a pedagogy based on narrative design has, over the years, made possible the development of two fields of research, the first one concerning the writing of content intended for immersion and the other one the design of devices hosting immersive experiments (LESCOP&AI. 2018).

In the set that we have created, the “grand salon” is thus raised, it gives this part of the set the feeling that it is a place of power and decisions, it is a land-

mark when it comes to knowing when history will take an important turn. The spaces of the pods, on the sides, like rotating barrels that are embedded in the main set, are like insert shots, they draw attention as if actors were developing a parallel action. We also have a control console located close to the camera which provides the equivalent of close-ups on the actors and insert shots and details of hands and buttons as they are viewed.

### CURRENT UNDERSTANDING: ISSUES

360-degree sets are quite rare (Figure 1). The exploration of filmed productions shows either purely digital productions or films shot in real environments. Browsing through the catalogues on offer easily proves this. In the design of this first set, which we launched in 2018, the aim was to design and build in the same way as we would do in the film industry, but with the constraints of 360° filming in mind. This particularly concerns the issue of the technical off-screen, which must be designed to hide elements that do not have to be seen in the image. The creation of a 360° set for a filming for virtual reality headsets implies a large number of precautions to be taken if we do not want to be harassed by a large

Figure 2  
A real set for a 360°  
virtual reality film.  
Photo P. Lescure

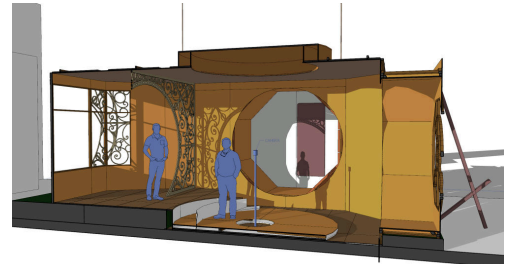


Figure 3  
Section of the set:  
the camera is in a  
central position. To  
create a tilt shot,  
the ground is raised  
while the camera  
itself can be  
lowered a bit.  
Model Archirep  
Studio, rendering  
L.Lescop

amount of post-production work. First of all, the acting space should not be too large. We have noted that beyond 3 meters from the camera, the details are not really discernible anymore, both because of the resolution of the cameras and, for the moment, the main obstacle, the resolution of the screens in the headset. This gives, for a fixed camera, a diameter of 5 to 6 meters in which it is possible to install a set of actors. However, it is possible to create background spaces or very large backgrounds, which gives a real feeling of openness, but one cannot place narrative elements that would not be well discriminated by the spectator. It should also not be to the detriment of the need and willingness to understand and empathize with the actors' acting (Figure 2).

Unlike what one would generally imagine, 360 degree film for a virtual experience is not an extension of the classic film. With a 360° camera, it is indeed not possible to frame in close-up or medium or overall. It is up to the filmed character to adjust these shot values by getting up more or less close to the camera. With care, however, the short focal lengths

of the cameras soon produce grotesque effects. Similarly, high angle or tilt shot will not easily be possible. If it is feasible to move the camera (slowly) to re-frame the scene, it will be preferable, as in the theater, to build in parts of the set that allow a view from above or the opposite angle. The staging will position the characters in the right place at the right time to achieve the desired visual effect (Figure 3).



Panoramic framing also implies that the lighting system should be integrated as much as possible into the diegetic space. This requires imagining solu-

tions to dim the light and to avoid hot spots that are unattractive by burning part of the image. The other challenge is to properly distribute the lights sources. A scene where the light would be concentrated in one point would complicate the stitching, that is to say the assembly of the various filmed views to compose a 360° image. This is one of the problems encountered when filming outdoors in natural light and when the sun is very bright. It is also what distinguishes the qualities of cameras on the market.

### RESEARCH QUESTION: WHAT KIND OF NARRATIVE GRAMMAR FOR A 360° VIRTUAL EXPERIENCE

The testing of the construction materializes theoretical questions about narrative grammar for virtual reality (Figure 4). The first set of questions concerns the transposition of the composition of a frame from a plane image to a 360° image. We have seen that it is obviously not possible to change the framing of a shot with a panoramic camera, but it is possible to organize the space and the movements in this space to suggest close-ups, inserts, wide area shots and even camera movements such as panning or traveling. There is another element of film grammar that concerns editing. Kulechov and his pupil Eisenstein showed very early in the history of cinema how to give meaning and symbolism through editing. In immersion, as we mentioned, direct transposition is not possible. A succession of sequences can be considered, but transposing the art of editing is against the very nature of the medium. In fact, the search for an equivalence with cinema wears itself out rather quickly. On the other hand, analogies with the theater are much more fertile. In the same way as in the theater, the playing space is entirely delivered to the spectator and as in the theater, pace, which could be compared to the editing process, the dynamics are given by the actors' performance (Pavis 2013). Intense, stirring, voluble, it induces haste and forward running, calm and soothed, it will transmit feelings of dullness or serenity. And as in the theater, over-framing can be done by set elements or by light.

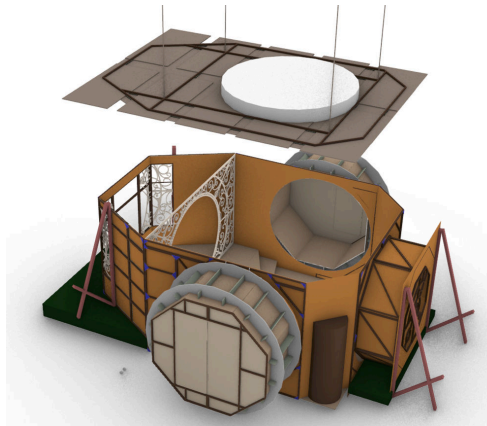


Figure 4  
3D model of the set.



Figure 5  
Film director Marc Caro staging at distance. Photo P.Lescure

Narrative implies the appropriation of a point of view. This point of view facilitates empathy with the characters and gives the story its tone. In 360° virtual reality, the point of view requires an intra-diegetic viewpoint. The spectator is physically in the story and for this reason asks for his position to be clarified. There are three kinds of points of view. In the first, the spectator is a ghost and his presence, invisible, does not disturb the course of the story. In the second, the spectator is present in the story as an inactive witness and in the third, he is a participating spectator-actor, which, consequently, requires a decision on whether or not to show a visible body. Many examples illustrate all these solutions, resulting in works ranging from passive contemplation to active participation.

The actors' acting is also to be compared to that of the theater. The movements must be fairly clearly expressed and the gestural dynamics must be legible. During the shooting of the film *Dans la Lune* with Marc Caro, we saw a clear difference in the cultural background between the actors from the theater and those from television and cinema. Staging of the actors did not follow the same standards as in cinema, but rather those of the theater staging. Filming at 360° requires that the director cannot be physically present on the set, he has to be at a distance, which confuses film actors (Figure 5). Before clapping, all the indications must be incorporated and the adjustments are marginally made during the play.

The question is therefore to understand how the extra-diegetic space will shape an efficient intra-diegetic experience, according to two criteria: a space to play and create when the design process is carried out and a space of astonishment and fascination when the experiment is made. We believe that these questions lead to the definition of a narrative grammar for a 360° virtual experience.

## FINDINGS: DESIGNING THE OFF-SCREEN

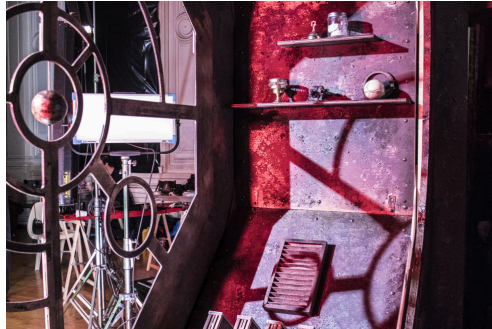


Figure 6  
Off-screen visible  
outside the set. It is  
where  
extra-diegetic light  
are installed. Photo  
P. Lescure

It is quite obvious to think that in a 360° space the off-screen no longer exists. In fact, it's more complicated than that, and the off-screen still exists, it's just defined differently. Traditionally, the off-screen is that space that is not seen outside of the stage frame in a theater or the camera frame in a movie.

The off-screen therefore has two main functions: it extends the diegetic space into the spectator's imagination (the spectator imagines continuities in what is hidden from him), and the off-screen offers opportunities for the technicians to install equipment that helps in creating the image: usually, we will find off-screen projectors, microphones, and many other things (Figure 6). So there are two kinds of off-screen depending on whether you are a spectator or a director, for the first it is the projection of the imaginary, for the second, the technique.

This frame that defines the off-screen is moving in RV, it means that nothing can escape the view, which can greatly hinder the shooting process. Céline Tricart has well described the constraints of shooting at 360°. For her film *Marriage Equality VR* shot in 2015, the great difficulty was to hide the technical team, who in the bushes, who in the trees, who behind street furniture (Tricart 2017). The off-screen should therefore no longer be defined as being outside the filming frame, but rather outside the field of vision. It is no longer to be considered laterally, but in depth. This means that the off-screen becomes what is out of the field of vision. For the construction of our set, it was consequently necessary to determine this out-of-field of vision, which was done with the help of the Isovist. From a given point, it is possible to fire rays in all directions and thus visualize the portions of space seen and the portions of space hidden. In this way, we were able to determine, by making the point of the ray shooting coincide with the camera's point, the volumes of space invisible to the eye, our famous deep off-field. These volumes can therefore be occupied by technique or by accessories, we are certain that they will not be visible to the camera.

The decor being a confined space, the problem was relatively simple, it mainly concerned the placement of the background visible through the bays of the spacecraft. As the background was painted on a constructed support, the distance and surface had to be very precisely adjusted to match the physical constraints of the studio. To do so, we used the T4SU tools developed by Hartwell and Leduc (Hartwell-

Leduc 2016) dedicated to sunlight, but with a very good Isovist module (Figures 7, 8). T4SU is a free plugin, developed for Sketchup. It calculates cones of visibility from a given point and thus gives the volumes of vision. It is also possible to have the area of intersection between the volume of vision and the affected surfaces, which allowed us to determine very precisely the areas to be worked on for the set. Grasshopper definitions were also tested, but T4SU's ease of use made it the preferred tool (Figure 9). However, for future developments, we know that a Grasshopper definition will allow us to obtain the unseen volumes, which will be very useful for more complex sets.

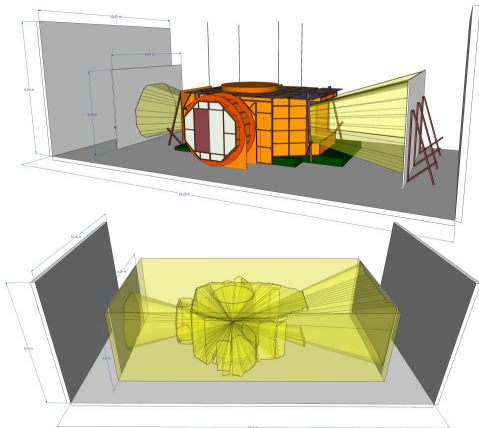


Figure 7  
One of the key issue is to only construct what is going to be seen in the image whatever the format is. Isovist helped defining the available surface for the background, and then the built result. Illustrations L.Lescop



Figure 8  
Positioning of the background for projection or post-production. Photos L.Lescop

The isovists used to determine the off-field of the 360° camera set have also been tested to understand the resolution issues of the 360° camera. Indeed, quite logically, a single pixel will cover a larger area as the distance increases. We can therefore establish a relationship between the distance of the surfaces of the set and the resolution of the details to be built or painted. It is useless to put a poster at a distance if it will be barely visible or readable. And, once again, the additional constraint doubles with the definition of the media to see the film, quality headphones or telephone. To meet the standard of the market's systems today, we have opted for a definition of 3840x1920. It is an equirectangular image that will then be mapped onto a virtual sphere. So there are 7,372,800 pixels to be distributed, with each pixel describing a projected surface area that can be determined. We do not really need a very complex calculation to guide us in the creation of the scenery, on the other hand, knowing that at a certain distance the resolution will already be half as high makes it possible to greatly anticipate the way in which visual information will be processed. It is the orders of magnitude that are interesting.

A fairly simple definition has been put together. The set modeled in Sketchup is imported with the Trimmed Planes option in order to have some Breps. In Sketchup, each object has been grouped and put on a different layer for an easier management afterwards. In Grasshopper, a point is placed which indicates the position of the camera. A UV sphere is used to visualize the resolution of the image. A vector follows the normal of each face of the sphere. A collision test is performed between this vector and the set and the background. This creates a volume which is then tested in Boolean operation with the elements of the set. It is the footprint of the tiling of the sphere that gives a grid printed on the decor and thus gives an idea of the resolution of the image as a function of distance (Figures 10, 11).

At the moment, Grasshopper's tests show errors if the resolution of the sphere is too high. This question will be the subject of further tests.

Figure 9  
 Except of the  
 Grasshopper  
 definition. III.  
 Lescop

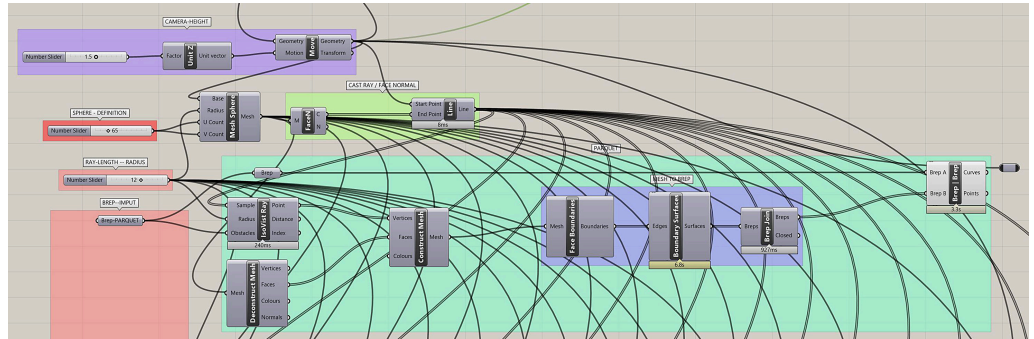


Figure 10  
 Definition grid  
 calculated with  
 Grasshopper. III.  
 L.Lescop

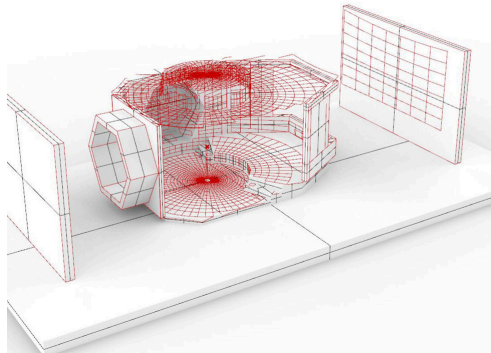
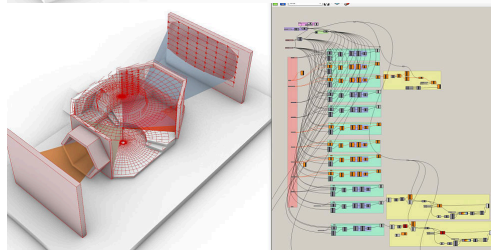


Figure 11  
 Visualization of the  
 360° image  
 resolution with a  
 grid. III. Lescop



### CONTRIBUTION: WRITING FOR A 360° REAL-VIRTUAL SPACE

One of the first conceptual obstacles concerning 360° writing or more globally for immersion is the relation

to temporality and more specifically to what is called “real time”. Immersion, lived as an embodied experience, may imply that temporal continuity is made identically or at least according to the same rules. However, the very nature of the concept of narrative implies the mastering of the temporality with which it will be played out. The creation of a narrative rests on the choices made in the organization of time, which can be accelerated, slowed down, cut or shifted at will. It is this very reorganization of temporality that makes a narrative; without it we are only in a voyeuristic posture waiting for an uncertain event. In the world of cinema, Robert McKee’s book “Story” serves as a reference to describe the stakes of the filmic narrative (McKee 1997).

Writing for 360° therefore requires controlling a space and a time that are not necessarily the equivalent of reality, but rather perceived rhythms that match the beats of the narrative. To put it another way, the narrative does not take place in a continuous space-time but in a discrete space-time. An illustration of this transformation of a contained space into a discrete space can be found in the world of video games. The game GTA (Grand Theft Auto) faithfully reproduces the city of Los Angeles in its opus V, which can be travelled in all directions at will. The game is part of a narrative logic, however, and for this reason the stakes must be renewed to maintain interest. Two different temporalities coexist, that of the diegetic space and that of the player. While one has





Figure 12  
Dans la Lune,  
during the  
shooting. Above on  
set, below outside  
the set in the  
control area. Photo  
M. Kolchesky,  
montage L. Lescop



Figure 13  
Preparing the shot.  
Photo P.Lescure

the feeling of living everything “in real time”, a whole day lasts only 8 minutes while a full hour passes in 2 minutes without having the feeling of being in an accelerated time. The space that is supposed to be embedded in reality also has ellipses and finds shortcuts to go from one point of interest to another. This narrative ellipse, which in a cinema montage would have been a cut, is in GTA the juxtaposition of two distant spaces, which made us say that there has been a conversion from time to space. (Lescop 2019)

The complexity clearly comes from the medium itself. Immersed in an experience of virtual reality, the time it takes to install oneself in the diegetic narrative is relatively long, one has to find one’s markers and find one’s bearings, whereas events can arise from any place (Figures 12, 13). This therefore implies the use of sequences of relatively long duration, or even the use of a single shot and a play for the actors close to that of the theater or the first films at the cinema. One of the most important issues that authors and directors writing on the subject try to understand is how to focus the spectator’s interest on

a particular point of virtual space (Nielsen&al.2016), (Elmezeny&al. 2018), (Pillai&Verma 2019). Jessica Brillhart (Brillhart 2016) was one of the first to theorize about the creation of points of interest that will, like spatio-narrative beacons, refocus the viewer’s attention where the director wants the action to be observed, what she called: probabilistic editing theory. This focusing, motivated by a sound signal or by a form of visual appeal, only partially resolves the management of the narrative space.



Figure 14  
Building the set.  
Photo L.Lescop



There are three different attitudes to the development of a narrative: the spectator can be synchronous with the unfolding of the events, he discovers the events at the same time as the protagonists, and the narrative follows the rhythm of these discoveries. Second option, the spectator is late relative to the protagonist(s) in the unfolding of the events. The narrative progresses by the succession of revelations that make the spectator catch up on the data of the events. Third option, the spectator is in advance and has better information than the protagonist(s). This is a bit like the “Punch and Judy” effect where we know that the gendarme is hidden behind the curtain. Abundantly used by director Alfred Hitchcock, this process works on the spectator’s anticipation of the course of events and on the screenwriter’s ability to work on time or to produce false leads (Snyder 2005)

## FURTHER DEVELOPMENTS

Offering a space in which a maximum number of constraints can be anticipated, a constructed set invites us to develop formal answers to theoretical questions (Figure 14). This exercise, combining research and pedagogy, in which we are involved while observing an emergent process that will radically disrupt our approaches. As mentioned at the beginning of this article, two headsets making a radical breakthrough appeared during the second half of 2019: the Oculus Quest and the Vive Cosmos. These headsets, especially the Quest, have been characterized by their ability to offer a free experience, without any physical connection, over an extremely wide area of action. This means that we enter a new universe in which the spectator is really a spectator-actor interacting with what is happening around him. Entirely new paradigms are thus being put in place, paradigms that shall be on the agenda of our forthcoming teachings.

## ACKNOWLEDGEMENTS

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