

Towards a Morphogenesis: Light in Xenakis's Work

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Proceedings of the *Xenakis 22: Centenary International Symposium* Athens & Nafplio (Greece), 24-29 May 2022 - <https://xenakis2022.uoa.gr/>

Abstract

This research examines light in Xenakis's *oeuvre*. The article presents a survey and analysis of Xenakis's use of both natural and artificial light. It allows us to grasp Xenakis's broad range of design strategies. Morphogenesis models were used as the analytical tool to offer a new perspective on light transformation and composition. A form-time scale framework was introduced to develop a deep understanding of Xenakis's composition of space via light form transformations.

1. Introduction

Light, in Xenakis's *oeuvre*, is a material that creates space, generates patterns, changes colours, evolves forms, and composes movement. Light connects his two vocations: architecture and music. For him, *real* architecture is a combination of space and light proportions (Xenakis, 1992), and “everything in light is close to music” (Xenakis, 2008).

From the shape of the Algerian olive oil container for the “light cannons” at *La Tourette* (1954-59) to the “anemone” laser configuration in *Diatope* (1978), Xenakis implemented morphological approaches in light compositions. Unlike static shapes, the light grows, transforms, and evolves. In biology, an organism's shape transformation, development, and growth process are called *morphogenesis*. This paper utilises morphogenesis models as the analytical tool to offer novel perspectives on the light transformation and growth in Xenakis's compositions.

In this research, I examine Xenakis's light from two categories: *natural light* and *artificial light*. Direct and indirect light from the natural environment are forms of natural light. The interior light of the *Convent of La Tourette* (“light cannons”, “machine guns”, and “undulating glass panes”), and the “path of light” of *Villa Mâche* (1966-77) belong to this first category. The artificial light category includes artificially generated light sources, such as lasers, electronic flashes, bonfires, torches, and searchlights. I focused on the “streetlight” at the *Unité d'Habitation Marseille*, as well as Xenakis's *Polytopes*, specifically the *Polytope de Montréal* (1967), the *Polytope de Cluny* (1972-74), the *Diatope* (1978), and the *Polytope de Mycènes* (1978).

In this paper, I used two digital morphogenesis models to analyse the light forms: *tip growth* and *stochastic form growth*. As an emerging computational design method, digital morphogenesis has great potential to investigate these light-based projects thanks to their close relationship with morphology theories, mathematical models, and digital techniques.

Furthermore, I introduce a form-time scale framework to develop an understanding of Xenakis's light compositions. Xenakis's light works have significantly influenced the media arts field. This article surveys a broad range of light design strategies employed by Xenakis spanning more than two decades of his career. Based on the form growth analysis of Xenakis's light works,

computational morphogenesis suggests a new system to investigate the design process and to develop future multimedia arts.

2. Xenakis's natural light projects

Sunlight, the source of energy for life on earth, travels 8 minutes and 20 seconds from 150 million kilometres away to the earth (Cian, 2013). Xenakis developed a series of approaches to design daylight in architectural space that uses direct light, indirect light, and a combination of both. In the natural light category, we analyse projects at two different geolocations. The first one is Xenakis and Le Corbusier's collaborative project, *Convent of La Tourette*, near Lyon, France. At this location, the day length is 15.75 hours in summer and 8.6 hours in winter. The second project is *Villa Mâche* located on the island of Amorgos, Greece, with a day length of 14.65 hours in summer and 9.5 hours in winter.

I focus on five specific light designs: the "light cannons", the "machine guns", the "undulating glass panes", the "path of light" at *La Tourette*, and the "path of light" at the *Villa Mâche*. Xenakis' design approaches can be grouped into three strategies: *protrusion*, *perforation*, and *screen*. In these light projects, he made significant contributions to daylight design using both direct and indirect sources.

2.1. Protrusions from an architecture's skin

La Tourette's church features two essential light components, "light cannons" (Figure 1) and "machine guns" (Figure 2). These elements protrude from the ceiling to the exterior architecture's skin, just like living organisms. One morphogenesis model that describes these forms is *tip growth*. In other words, living cells evolve into an elongated cylindrical cell morphology with rounded tips. In biology, *tip growth* refers to cells deformed using their membrane and its wall by adding new proteins and their extension (Pelce, 2000). The morphology of coral is an excellent example of *tip growth*. The three "light cannons" grow inconsistently in different dimensions, heights, and directions, whereas the "machine guns" grow steadily in relatively the same size, height, and direction.

The "light cannons", located at the north lower chapel of the church, use indirect light to create a space of contemplation. The north chapel is a grand-piano-shaped crypt apse. Its floor surface is approximately 180 sq metres, and an average ceiling height of 4 metres. This cave-like space is surrounded by an undulating concrete wall that inclines inwards. A partition wall (approx. 2 metres high) visually divides the spaces between the lower chapel and the church nave. Light and sound connect the two spaces.

Xenakis borrowed the shape of Algerian olive oil tins for the "light cannons" form (Xenakis, 2008). The internal surfaces of the "light cannons" are irregularly curved concrete walls painted in white, red, and black, respectively (Figure 3). The light contours from the ceiling are three organic circle shapes varying in sizes, with white as the largest circle, red at the middle, and black as the smallest one. Starting from the interior ceiling, the "light cannons" tip grows towards the sky, like fungi, in different directions. The white "light cannon" on the east protrudes from the ceiling and grows towards the northeast. The red "light cannon" in the middle extrudes to the north. And the black one on the west points its tip to the northwest.

Natural light washes the internal surface of the "light cannons" to provide indirect skylight to the crypt and lateral lights of the church (Figure 4). The 14-metre-high church adjacent to the lower chapel's south blocks direct sunlight to the "light cannons". The only direct light that comes into the lower chapel is the morning light from the east during midsummer (Walker, 2016). With the variety of colour, proportion, protrusion direction, and skylight-facing orientation, the white "light cannon" has the brightest luminosity, and the black "light cannon" has the lowest fluorescence.

Unlike the inconsistent *tip growth* of “light cannons”, Xenakis designed seven unified polygons and protruded them from the sacristy’s ceiling towards the south (Figure 2 and 5). The seven quadrilateral shapes of “machine guns” extrude in two rows. There are four “machine guns” in the front and three in the back. It is worth noting that this arrangement also suggests a natural morphology—the alternate leaf pattern. In addition, similar to the pointed quartz crystal, the “machine guns” have sharp angles, which point to the courtyard of the Monastery. Xenakis oriented these irregular concrete prisms and carefully tilted the top glazing panel. With careful calculation and sun path study, the “machine guns” invite direct sunlight into the church nave during the two yearly equinoxes (Xenakis, 2008).

Xenakis used a protrusion approach on an architecture skin to design daylighting in his collaboration with Le Corbusier. This approach is an excellent example of a poetic relationship between morphology (curved surface, geometry, proportion, arrangement, etc.) and natural light. The “light cannons” and “machine guns” suggest a morphogenesis model of *tip growth* as an approach to develop irregular-shaped lighting devices to create a poetic daylight effect for a space of ritual.



Figure 1: A view from north-east of the three “light cannons” protruding from the roof of the piano-shaped lower chapel at La Tourette. The wall of the chapel is an undulating concrete surface that inclines inwards toward the interior space. The church blocks most direct light from the south. (Photo by author in May 2016).



Figure 2: A view from south-east of the seven “machine guns” protruding from the roof of the sacristy. Four in the front row, and three behind. (Photo by author in May 2016).

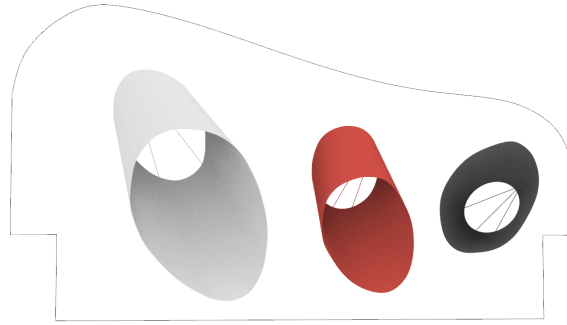


Figure 3: A view from the bottom of the “light cannons” with the ceiling contour. The white “light cannon” on the east grows towards the northeast. The red “light cannon” in the middle extrudes to the north. And the black one on the west points its tip to the northwest. (Digital reconstruction by author in March 2022).



Figure 4: A View from the bottom of the red and black “light cannons” with the partition wall underneath (photo credit: 51 la tourette CFX © Famille I Xenakis DR).



Figure 5: A View from the bottom of four polygon shapes from the “machine guns” (photo credit: 30 la tourette CFX © Famille I Xenakis DR).

2.2. Perforations on an architecture’s skin

Musical “neumes” and their light paths, a recurrent leitmotif, has become one of Xenakis’s signatures in his architectural projects (Kanach, 2008). Every light path that Xenakis designed is specifically created for a unique site. The light path *perforates* the architecture’s skin by replacing a solid wall with glazed panes. For example, we can find such implementations on the rooftop stairwell bulkhead (Figure 6) at *La Tourette* and on the façade of *Villa Mâche*. The light pattern grows stochastically from a relative centre point to a neighbouring position. One model describing such a type of stochastic growth is a *random walk*. In mathematics, a *random walk* is a stochastic process that starts from a centre point of a lattice and grows on paths based on probability. In nature,

crystallisation is an example of such a stochastic growth form.

Although it seems to grow randomly, the realisation of the light path processes functional, meaningful, and aesthetic goals. The light path at *La Tourette* is the first project where Xenakis applied the perforation approach to a lighting design. If we place the floor plan of the complex next to the "path of light" of the rooftop stairwell bulkhead, one can easily see the visual connection between the circulation plan (Figure 6) with the geometry perforated on the wall. The highlighted area represents the walking paths of corridors, the lower church, the sacristy, and the atrium. To be more specific, these are the locations of Xenakis's lighting design: "light cannons", "machine guns", and "undulating glass panes". In other words, Xenakis abstracts his "path of light" to develop a *random walk* that starts from the atrium. It is a symbolic manner for the convent. The walking path of everyday life at the convent is closer to the sky–heaven.

Facing the southwest, daylight at *La Tourette* ends at the "path of light" on the rooftop every day. A perfect location to bid farewell to the daily natural light cycle at the convent. Direct and indirect light comes through the narrowed cuts of the wall into the staircase. Unlike other lights that create space, the slim light beam divides this space. The chiaroscuros and proportion between light and space is an essential design element in Xenakis's architecture projects.

The light paths at the *Villa Mâche* are a combination of random growth paths and stochastic distribution of windows (Figure 7). The distribution of such "neume" windows first appeared in the *Unité d'Habitation de Nantes-Rezé* (1950-54), a project also realised in Le Corbusier's studio. Xenakis designed the façade of the roof kindergarten using stochastics. At the *Villa Mâche*, we can find the continuous light paths and the detached windows intertwined together, based on probability theory.

Wall openings are a bridge to nature. Xenakis used the openings to frame the natural landscape from the interior view; meanwhile, the natural light also arranges the interior space by generating visual contrast. The perforations on the façade of the *Villa Mâche* are mainly facing north. In addition, a perforation was also applied to the ceiling in the living room. The narrow cut on the ceiling creates a laser-like light beam that splits the space into two. Although indirect light is the main source, the white surface on the wall and the bright skylight create a strong illuminated spatial composition for the interior space.

The realisation of the *Villa Mâche*'s façade not only frames the landscape views, but also presents a meaningful abstraction: the composer François-Bernard Mâche's initial. We can identify various abstractions of the letter "F" on the façade. For example, the square window and the light path in the living room compose the letter "F" (Figure 8). Xenakis stochastically grew the light form to achieve a new aesthetic of lighting.

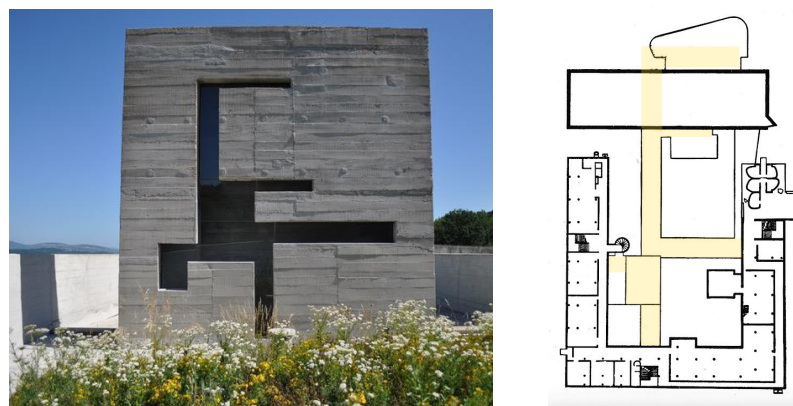


Figure 6: Left image: The "path of light" on the rooftop stairwell bulkhead on the terrace (*Escalier toit-terrasse, vue générale* © Famille I Xenakis DR). Right image: Light path abstract diagram on the floor plan of *La Tourette* (Plan from *wikiarquitectura*, diagram by author).



Figure 7: Interior view of Villa Mâche (10 Diapo Maison Mâche © Famille I Xenakis DR)



Figure 8: Interior view of Villa Mâche (7 Diapo Maison Mâche © Famille I Xenakis DR)

2.3. Screen: light acting as an architecture's skin

The last approach that Xenakis used in natural light projects is the *screen*, known as “undulating glass panes”. The natural light of “undulating glass panes” is not merely a light source. Light becomes part of the architectural body; for him, light is architecture. The first light that comes into interior space is the tip of the growth form. Based on the *tip growth* model, the relationship between the density of the light and the density of the concrete frame is inversely proportional. In other words, when the light's protrusion is high, the density of the concrete frames will be low.

Furthermore, the density and continuity in the “undulating glass panes” became Xenakis's musical expression in architecture. “Undulating glass panes”, first applied on the façade of the Secretariat in Chandigarh, is a modern architectural innovation by Iannis Xenakis and Le Corbusier. It appears in many of Le Corbusier's projects, as well as Xenakis's independent architectural works (Kanach, 2008). Perhaps, the most famous one is located on the west façade at the *Convent of La Tourette* due to its scale, proportion, and musical movement. The top two levels on the façade (Figure 9) are *Modulor* living cells, and the lower levels are musical glass panes. This façade embodies two architectural ideas: Le Corbusier's *Machines for Living In*, and Xenakis's music in

architecture.

Facing the northwest, the natural light illuminates the interior space. Selective direct and indirect light grows into the interior space through the glazing. At about 3.66 metres floor-to-ceiling height, light and shade perform a musical gesture inside. While walking at a constant speed, one can perceive dramatic light movements thanks to the continuous change of the concrete frames' density. The rhythmic experience is a continuity of light transformation. A new lighting aesthetic has emerged through Xenakis's music composition, intellectual contemplation, and mathematical abstraction.



Figure 9: A view of the west façade. Two levels of modulator house unite on the (Photo by author in May 2016).

2.4. Analysis of natural light forms and time

Time and duration are important criteria for light composition. On the other hand, growth rate is an important parameter in morphogenesis analysis and design. If we have the duration and the form, we can extrapolate an estimated growing model. Table 1 shows a summary of five natural light projects. The time scale is based on hours. For example, the daylight event of the “light cannons” happens once every day; the direct light event of the “machine guns” happens once every six months. For the lights’ surfaces, three design strategies have different calculation methods. In the protrusion group, the light surface is the area that reflects and diffuses natural light. For example, the light surface area for the “light cannons” is the sum area of the three cones. For the perforation group, the light surface is the wall opening area. Lastly, for the screen type, the light surface area is the whole screen size. In section 3.3, we will discuss the analysis of forms and time scales.

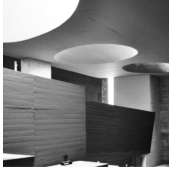


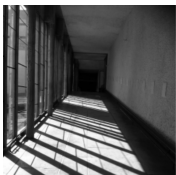
Natural Light Project	Location	Morphogenesis Model	Light Type	Light Surface Area (\approx sq metre)	Light Event Time and duration
 <p>Light Cannons (1954-1959)</p>	Couvent de La Tourette (Lower Chapel)	Tip growth	Indirect light	12	Every 24 hours. Daylight = 15.75 hours in summer, and 8.6 hours in winter.
 <p>Machine guns (1954-1959)</p>	Couvent de La Tourette (Sacristy)	Tip growth	Direct and indirect light	3.5	Every 24 hours. Daylight = 15.75 hours in summer, and 8.6 hours in winter. Direct light every 6 months.
 <p>Path of light (1954-1959)</p>	Couvent de La Tourette (roof stairwell bulkhead)	Stochastic growth	Direct and indirect light	1.5	Every 24 hours. Daylight = 15.75 hours in summer, and 8.6 hours in winter.
 <p>Path of light (1966 – 1977)</p>	Villa Mâche	Stochastic growth	Direct and indirect light	2	Every 24 hours. Daylight = 14.65 hours in summer and 9.5 hours in winter.
 <p>Undulating glass panes (1954-1959)</p>	Couvent de La Tourette (hallways, meeting rooms, refectory, library, etc.)	Tip growth	Direct and indirect light	140	Every 24 hours. Daylight = 15.75 hours in summer, and 8.6 hours in winter.

Table 1: Light form and time scales in Xenakis' natural light projects

3. Xenakis's artificial light projects

After working with natural light, Xenakis came to see the light – in general – as an architectural gesture. He began to envision light as a material in his compositions in addition to time and duration. As he noticed, “man has access to events made of real light thanks to—for the time being—lasers, electronic flashes, light projectors and computers” (Xenakis, 2008).

Under the artificially light category, I will focus on five projects: the snail-shaped light fixture in the *Unité d'Habitation Marseille* (1951-52), the *Polytope de Montréal*, the *Polytope de Cluny*, the *Diatope*, and the *Polytope de Mycènes*. These projects can be classified as *static* and *dynamic* types. The static type is a light form that does not change over time. In contrast, the dynamic type is a light form that evolves and changes over time. The *Polotypes* belong to the dynamic type. Through artificial light, Xenakis achieved a landmark in light art and paved the road for a new type of art: multimedia.

3.1. The static light form of snail lamp

In his first¹ artificial light project, Xenakis used fluorescent tubes as a basic light source. The snail-shaped lamp (Figure 10) is an organic form lighting fixture for the corridors of the *Unité d'Habitation Marseille*. Designed by Le Corbusier and Xenakis in 1951-52, the lamp can be rotated in several directions. The hidden fluorescent tubes wash the curved sheet-metal surface to achieve an indirect lighting effect. The bent reflecting surface is approximately 0.35 sq metre (0.7m in length and 0.5m in width). The shape is closer to a golden spiral; as the name suggests, it resembles a seashell of a snail. The light glows from the inside to the outside, following a Fibonacci sequence. Once the lamp is turned on during the night, it provides a curvature shape of light. As Sharon Kanach observed, “This organic shaped independent structure creates an interesting contrast with the pronouncedly angular aspect of the main building” (Kanach, 2008).



Figure 10: Large snail-shaped lighting fixture (1951-52) along the corridors of the *Unité d'Habitation Marseille* (photo by author in May 2016)

3.2. The growing forms of the Polytopes' light

After the success of “musical glass panes”, Xenakis had new thoughts on approaching light: speed

¹ This paper considers the snail lamp as the first project in the artificial light category. As a side note, Xenakis once directed a tragedy based on lighting, and lighting changes in his 20s.

and form. In his *Polytopes*, Xenakis used a variety of artificial lights, such as electronic flashes in Montréal, lasers in Cluny, and bonfire and searchlights in Mycenae, among others. Although the sites and scales were varied, there was a unified strategy in his *Polytopes*: using lights to compose movement and evolve forms. In Sharon Kanach's words, a "musicalization of space".

Both in indoor and outdoor settings, his *Polytopes* inhabit a relatively dark environment, which gives Xenakis an "empty" universe in which to create light. Like the chapel at *La Tourette*, without light, there is nothing. To enact his ideas of light form, Xenakis used lattice structures, such as steel cables or grid systems, on to which the artificial light sources were attached. For example, he designed five curved surfaces that intersected using 200 steel cables at the central void of the France Pavilion in Montréal (Figure 11). These cables create hyperbolic geometries for the dynamic and colourful light surfaces during the performance. In Cluny, since it is forbidden to touch the venue's historical walls, Xenakis used a metallic grid to construct a scaffolding structure next to the vaults and walls (Figure 12). Lasers, mirrors, and speakers are positioned at the desired spots; meanwhile, the participants still have a spatial sensation of the original ancient Roman bath. In his *Diatope*, the interior surface of the vinyl PVC fabric was coated in grey to create a dark space for the light performance (Kanach, 2008, Kiourtsoglou, 2018). The most spectacular *Polytope's* site was Mycenae which took the audience back some 3600 years. After sunset, the ancient land of civilization became the composer's canvas. If the other *Polytopes* lights were grown upon a metallic network, the light of the *Polytope de Mycènes* was grown based on the history of human society. We thus become witness of the evolution of civilization through light.

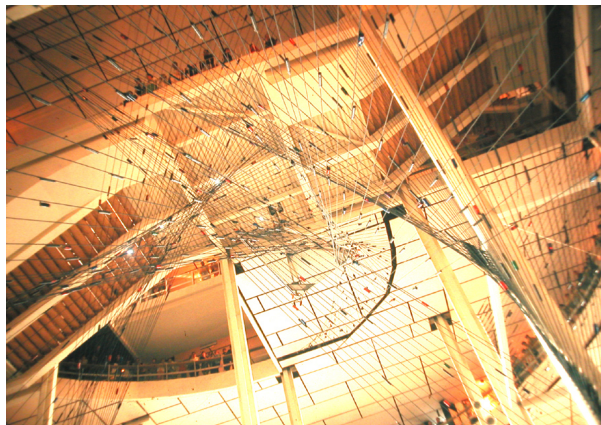


Figure 11: Photo of the Polytope de Montréal (Collection of Françoise Xenakis). *Music and Architecture*, Iannis Xenakis and Sharon Kanach, Hillsdale N.Y: Pendragon Press, 2008. Page 206.

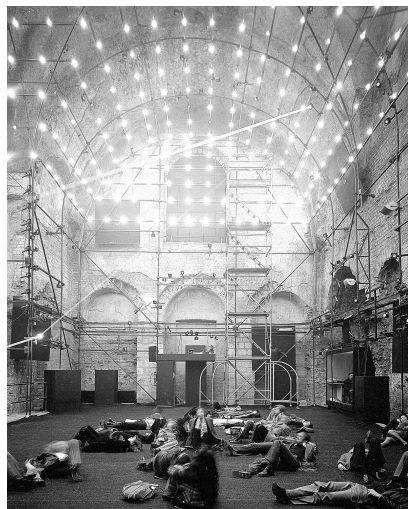


Figure 12: Light flashes on metallic grids for Polytope de Cluny in situ (Collection of Françoise Xenakis). *Music and Architecture*, Iannis Xenakis and Sharon Kanach, Hillsdale N.Y: Pendragon Press, 2008. Page 227.



Figure 13: An interior view of the *Diatope*. Rastoin, Bruno (1954-2020). Photographer, “[*Diatope* 1978-79, Paris, photo couleur : vue de l’intérieur à hauteur du spectateur, lasers 5],” Centre Iannis Xenakis, accessed March 22, 2022, <http://www.centre-iannis-xenakis.org/items/show/4006>.



Figure 14: *Polytope de Mycènes* (Collection of Françoise Xenakis). *Music and Architecture*, Iannis Xenakis and Sharon Kanach, Hillsdale N.Y: Pendragon Press, 2008. Page 234.

3.3. Analysis of artificial light forms and time

With digital technologies, such as lasers, flashes, and computers, light becomes a material that creates space, generates patterns, changes colours, evolves forms, and composes movement. More importantly, light can change its speed and design on a smaller scale. For example, the frequency of the fluorescent tube in the snail lamp is 100-120 Hz. Our human eye can barely perceive this frequency range. Once the light is on, the static shape is formed. The illumination of the sensitive range for human vision is 10-25 Hz. In the *Polytopes*, the flashlights' frequency falls in this range. Table 2 summarised four *Polytope* projects' artificial light sources and light event durations. In these four projects, Xenakis's light composition ranges from 6 minutes to 1.5 hours. It is worth underlining again that light became a musical expression for Xenakis and allowed him to explore new forms. That is general morphology.

To develop an understanding of the form-time relationship in Xenakis's *oeuvre*, I identified ten discussed projects in an axis of the form-time scales system (Figure 15). Green star is labelled as a natural light project, and white star as an artificial light project. The X-axis is the time scale from second to year. The Y-axis is the form scale from centimetre to kilometre. As shown in the image, the time duration of the natural light projects is relatively the same. It suggests that the form scale would be more important for a variation and design purpose. On the other hand, Xenakis's artificial light projects varied in both time and form scales based on the site and goals.

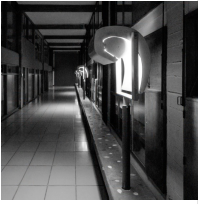

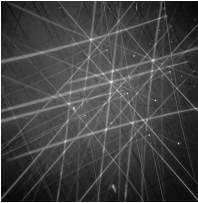
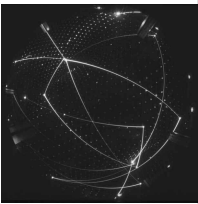
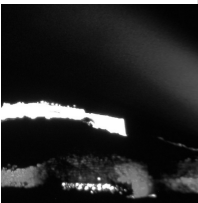
Light Project	Location	Light Source	Light Abstract Form and Surface Area (≈)	Light Event Time and duration
 <p>Snail-shaped lighting fixture (1951-52)</p>	Corridors at the Unité d'Habitation Marseille France	Fluorescent tube	Snail (The curved surface is approx. 0.34 sq.m)	100 - 120 times / second (not perceivable by the human eye)
 <p>Polytope de Montréal (1967)</p>	French Pavilion (currently the Casino de Montréal) Canada	1200 Electronic flashes (800 white, 400 colours in yellow, red, green, and blue.)	Rivers, arms, leaps, wisps of fire, etc Surface area estimated 1,300 sq metres	25 times per second. 9000 times during the six minutes of the performance. The show ran once every hour.
 <p>Polytope de Cluny (1972-74)</p>	Thermes de Cluny, Paris, France	Three lasers (green, yellow-green, and blue) Mirrors, and 600 white xenon tubes	Geometrical: circles, parallel, crossing lines, spirals, arcs, etc Natural: rivers, lotus, anemone, etc. 300 sq metre	25 times per second. The performance lasted 24 minutes. Several performance per day.
 <p>Le Diatope (1978)</p>	Place Georges Pompidou, Paris, France	1680 electronic xenon flashes (on cable network, wall of the shell, and under the glass-tile floor) 4 lasers (3 green, 1 red) 400 fixed or pivotal mirrors	Spirals, etc. 400 sq metres	25 times per second. The performance lasts 45'48"
 <p>Polytope de Mycènes (1978)</p>	The acropolis of Mycenae, Greece	Lasers, electronic flashes, bonfires, torches (torch-bearing children), and 12 searchlights, a bonfire, light between goats' horns, and fireworks	30,000 sq. metres	The performance lasted 1.5 hours

Table 2: Light form and time scales in Xenakis's artificial light projects

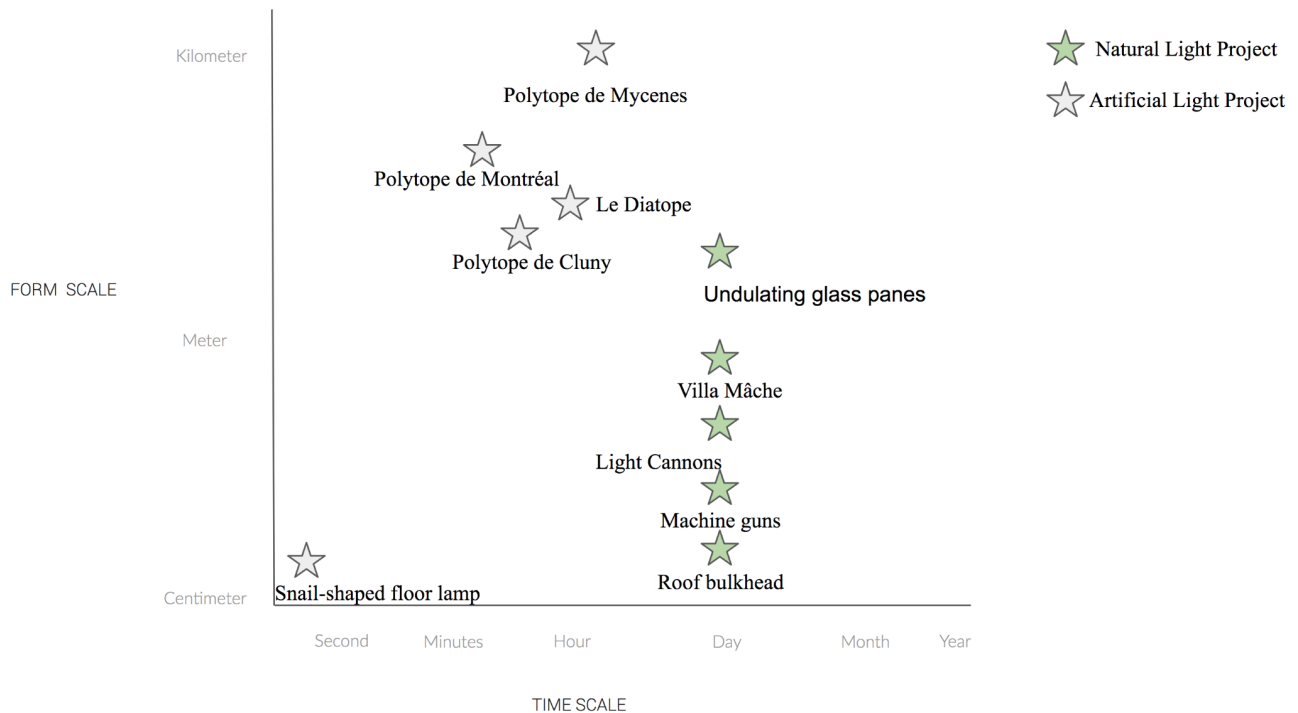


Figure 15: A form-time scales framework to analyse Xenakis's light works

4. Conclusions

Light in Xenakis's works has three phrases: light as architecture, light as music, and light as morphology. In Xenakis's early light work, we can find a series of form findings and explorations. From borrowing the shape of an olive oil container to the sharp polygon light guns, Xenakis used both geometric architectural elements and light form to express his ideas. That was light as architecture. A turning point happened during the completion of the undulating glass panes. Xenakis started to compose light with consideration of time and speed. During the period of *Polytopes*, the light slowly evolved and developed forms and patterns, which led to morphogenesis in multimedia composition. His light is poetic, dramatic, emotional, and powerful. Xenakis not only created a new aesthetic of light art, but also projected a future direction for the role of light.

Acknowledgments

I am grateful to Curtis Roads for his advice and encouragement. I am thankful to Sharon Kanach for her inspiration, guidance, and support. I sincerely thank the Centre Iannis Xenakis for making their digital archive available. I am also deeply grateful to Mâkhi Xenakis and Etienne Assous for making the Iannis Xenakis archives available to me. I owe a debt of gratitude to Juan Escalante for his feedback on this manuscript.

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