Nexus Network Journal
https://doi.org/10.1007/s00004-023-00655-x

NEXUS NETWORK JOURNAL
Architecture and Mathematics

RESEARCH

A Virtual Reconstruction of Gaudi's Skyscraper Hotel Attraction Using Physics-Based Simulation

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Accepted: 16 February 2023

Abstract

This article aims to provide a virtual reconstruction of the skyscraper Hotel Attraction based on the original documentation, which makes it possible to analyze the project and propose hypotheses regarding the contradictory information in the original drawings. The geometry of the project has been defined using a physics-based simulation, emulating Gaudí's methodology in his models. To define the curves, a model based on weighted hanging chains has been generated, using a system with springs and particles. This method has made it possible to precisely control the catenary deformation, avoiding the definition of each curve independently in favor of a unified approach. Over 300 m tall, the Hotel Attraction would have been the tallest skyscraper in the world at the time.

Keywords Antoni Gaudí · Hotel Attraction · Form finding · Hanging chains · Particle spring system · Virtual reality

Introduction

While he was supervising the construction of the Sagrada Familia in Barcelona in May 1908, Gaudí was supposedly visited by two American businessmen of unknown identity (Matamala Flotats 1960). They proposed Gaudí to design a hotel-skyscraper in Manhattan that was supposed to become a symbol for the American nation. Due to Gaudí's falling ill with fever, his dedication to the Sagrada Familia, and the distance between the two continents, the project was later abandoned. Had it been built, the Hotel Attraction would have represented not only a key asset for the city of New York, but also a milestone in Gaudí's career.

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Published online: 20 March 2023

Birkhäuser

Over 300 m tall, the Hotel Attraction would have been one of the first skyscrapers in Manhattan, and the tallest in the world until the construction of the Chrysler Building and Empire State Building two decades later (1930 and 1931). Gaudí's project was marked by unique organic volumes which, along with its complex decoration, would have made a notable contrast with the prismatic New York skyscrapers (Fig. 1).

The project was then forgotten until Juan Matamala, a former apprentice in the sculpture workshop at the Sagrada Familia in Barcelona, published a series of drawings of the skyscraper in his memoirs. The paucity of surviving documentation has shrouded the project in a certain air of mysticism, and some have even gone so far as to say that it never existed as such. Based on Matamala's drawings, interest in the skyscraper has encouraged architects, artists, and even a television series and comic to present their interpretations of it, but none made an attempt to rigidly stick to the original documentation.

The aim of this article is to carry out a precise virtual reconstruction of the project, following the original drawings of Gaudí that have been preserved, and allowing new documentation to be generated and the complex geometry of the hotel to be examined. While the documentation published by Matamala does allow Gaudí's project to be defined and understood, there are few surviving drawings of the hotel and these contain contradictions in the design, which led to a number of hypotheses regarding its reconstruction.

To define the geometry of the project, a method based on physics-based simulations (Kilian 2004; Rippmann et al. 2012) has been used, which allowed to obtain and control *weighted* hanging chains. The aim was to imitate the working methodology used by Gaudí in his models, avoiding the individual definition of each of the curves using CAD tracing or mathematical approaches.

The virtual model was made using Rhinoceros 7 and Grasshopper (Fig. 2), and then exported to a virtual reality system with Unreal Engine 5. A parametric approach made it possible to examine different hypotheses concerning facade finishes and openings (Ostrowska-Wawryniuk et al. 2022). The organic surfaces (facade and moldings) have been realized using the recent SubD technology

Fig. 1 New York skyline with the Hotel Attraction

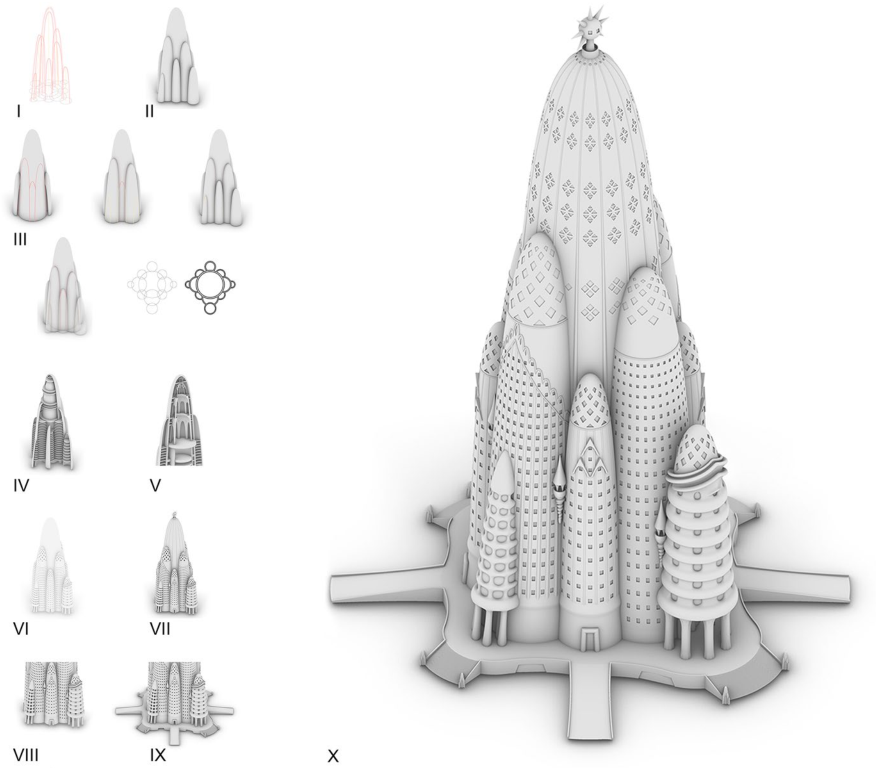


Fig. 2 Different stages of virtual reconstruction of the skyscraper

developed by McNeel, which allows the generation of high precision surfaces based on splines that create complex free forms with a high degree of accuracy.

Historical Context and Documentation

There is no known site for the project, since the American businessmen only required a sketch as a basis for raising money and a location would have been sought out afterwards. Supposedly, the two Americans decided to stay a few days in Barcelona in the company of Gaudí, whom they admired and knew from publications in the American Press. During that visit, Gaudí proposed that 'the projected construction […] should culminate in a great hall in homage to that great nation [the United States],' as well as 'surrounding it with gardens' (Montaner and Azara 2003: 41).

The plan was to complete the project within 7 or 8 years, during which Gaudí was to make successive trips to New York to supervise the work. He agreed with the two Americans to start work after around 3 years, enabling him to finish Casa Milá, Parc Güell, the church in the Colonia Güell, and to dedicate some time to the building of the Sagrada Familia.

Gaudí then had the misfortune to contract Maltese fever, from which he suffered the next 2 months. The virulence of the illness and his slow recovery affected the architect's strength that he was unable to undertake long journeys. 'His health [...] was the reason that prevented him from taking part in the building project,' as well as the 'imperatives of moral duty towards the temple of the Sagrada Familia' (Montaner and Azara 2003: 45), and together they put a premature end to the great hotel project in Manhattan.

In the wake of the bombing of Barcelona during the Spanish Civil War in 1936, Gaudí's documentation on the hotel was lost. The project was forgotten, and it was not until 1956 that Matamala published copies of the original drawings, which then passed from oblivion into legend.

The very authorship of the project has not been free of controversy. The only source of the original documentation was published by Matamala in his memoirs *Antoni Gaudí*, *my itinerary with the architect* (1960). This has led to doubts about whether Gaudí really was the author. Gueilburt (2007: 18), director of the Centre for Gaudinist Studies between 1993 and 2003, attributed the project entirely to Matamala's imagination, and Juan José Lahuerta, director of the Real Cátedra Gaudí since 2016, also expressed his doubts.

A variety of different research, on the other hand, validated Gaudí's authorship of the project, including the publications of the historian Juan Bassegoda (president of the Amigos de Gaudí association and director of the Real Cátedra Gaudí until 2000), and the thesis written by the architect Marcos Mejía López. Likewise, in 1917 the architect Ignasi Brugera made drawings for some office buildings in New York and, according to the testimonies of those who saw these now lost drawings, 'it is evident that Brugeras was aware of some of Gaudí's sketches' (Montaner and Azara 2003: 22). César Martinell, Gaudí's main biographer, writes that 'the construction of a colossal hotel building in the United States was proposed to Gaudí, with the suggestion that the building's originality and exoticism would overcome utilitarianism,' saying that 'it was his advanced plasticism and daring solutions that most impressed them about Gaudí' (Martinell 1967: 403). Matamala presented some drawings that he made, copying Gaudí's originals. These drawings represent plans and sections with a graphic scale, a number of perspectives, and a section of the so-called *Hall of Tribute to America*. Also included are a few sketches that are attributed to Gaudí himself.

The documentation presented by Matamala served as the basis for the interpretations or representations of later authors. We can highlight the geometric analyses and proposals by Hidalgo Herrera (2008), the entry of the *Real Cátedra Gaudí* (School of Architecture of Barcelona) in the competition for the World Trade Center and the exterior recreation of the Skyscraper for the television series *Fringe* (specifically the episode 'Over There'). Montaner and Azara also require special mention (2003), whose work brought together much of the data on the skyscraper and modelling by using early 21st-century CAD programs.

Several other authors also made their own interpretations of the skyscraper and its typology. In his famous work *Delirious New York*, Rem Koolhaas describes the Skyscraper as;

> a sheaf of stalagmites, combined to form a single conoid that is, unmistakably, a Tower. It inhabits a podium or island, connected by bridges to other islands. It stands aggressively alone. Gaudi's design is a paradigm of floor-by-floor conquest of the Skyscraper by social activities. (Koolhaas 1978: 105)

Inverted Catenaries and the Hotel Attraction

The use of arches following the geometry of the catenary is one of the key characteristics of Gaudí's architecture (Zerbst 1988; Lahuerta 1992). The fundamental principle for the design of these arches is based on the deformation of a cable, rope or chain without flexural rigidity, which is suspended between two points and deforms due to its own weight. The resulting form is known as a catenary, which, when inverted, functions mainly through compression, eliminating bending moments (Hooke 1675; Heyman 1999; Huerta 2006a). Equilibrium in a masonry arch can be visualized using a line of thrust, which represents the path of the resultant of the compressive forces through the stone structure (Block et al. 2006; Paris et al. 2021). This is a rational design process in which the resulting form is a structure optimized to work under compression, and explains why stone materials with high compressive strength are especially useful. Gaudí frequently used brick and ashlar.

These principles result in arches of a constant thickness which fit in with the anti-funicular form. In the case of the Hotel Attraction, there are also arches of variable thickness, which become less thick the further they are from the supports. Such arches can only be fashioned with the use of a *weighted catenary*, being the form that a flexible cord assumes if it was variable in width, with a hanging chain of differently sized or weighted links, or with variations in the density of the material or gravity (Johns 2005). An example of a weighted catenary can be seen in the famous Saint Louis Gateway Arch, designed by Eero Saarinen (Pelkonen and Albrecht 2006; Lastra 2022).

The term *weighted catenary* is not precise, however, it is possible to obtain practically any curve by means of a weighted chain, including a parabolic or circular arc. In this case, we really refer to a *flattened catenary*, the ideal shape for an arch that is tapered in a certain precise manner (Osserman 2010).

The equation for a flattened catenary is $y = A\cosh(Bx)$, which corresponds to the general equation of a catenary $y = A\cosh(x/B)$, when $A = 1/B$. The vertex of the catenary would thus be V (0, A), and its radius of curvature would correspond to $p = y^2/A$ (Bronshtein and Semendiaev 1980; Bukowski 2008).

When a cable, rope, or chain bears a weight much greater than its own (the latter being negligible), and this weight is uniform with its vector following the direction of the join of the focus and the vertex of the curve (normally vertical), the equation obtained will be a quadratic one, corresponding to a parabola (Billington 1985). For example, the equation of a parabola starting at 45° would be: $y = 1/x^2$; $(-1 < x < 1)$.

Defining equations allows the exact calculation of the geometry of arches or vaults, but it is not a practical approach in the context of architectural design.

Gaudí's chain models are famous, and his method would later be followed by architects and engineers such as Frei Otto or Heinz Isler.

Today, catenaries or parabolas can be drawn directly by using CAD programs, but when they are combined, the mutual deformations that occur are not easily predicted. However, performing digital simulations allows us to emulate the work that Gaudí carried out through his models (Fig. 3).

When a model is made with chains, these chains are not extendable (Truesdell 1960). The model used here to perform the simulations for the catenaries is based on a variation of the general model, where the catenaries are considered to be elastic. This would be equivalent to replacing hanging chains with weightless springs linked by particles on which the loads would be applied. The spring stretches in accordance with Hooke's Law (Piker 2013; Güzelci et al. 2022).

Using the particle-spring system, we have been able to rigorously reconstruct the skyscraper following the plans, without tracing the curves using CAD programs or mathematical methods. With this interactive approach we can simulate the behavior of the hanging chains, with the possibility of introducing variations that modify the shape of these chains.

The particle-spring system solves the problem of the dynamic equilibrium, equivalent to the static equilibrium (Kilian and Ochsendorf 2005). The motion of the particles is governed by Newton's second law and the force in the springs by Hooke's law of elasticity. According to Hooke's law, the force of a spring is $F=k\ \varepsilon$, where k is a stiffness constant and ε is the elongation or variation in length ($\varepsilon=l-l_0$). In our model, l_0 will be the remaining length while l will be the lengths defined as targets to be achieved in our simulation.

In a particle-spring system, the forces of the springs can be expressed as internal force densities of each spring connecting two particles (Bhooshan et al.

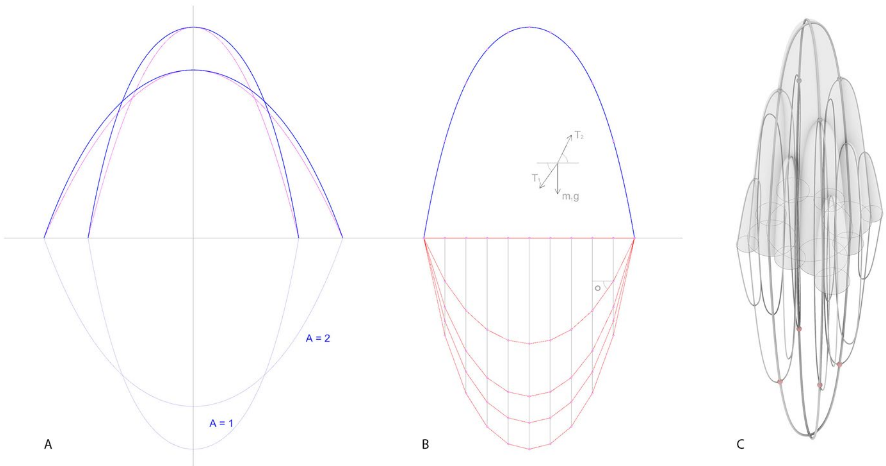


Fig. 3 **A** Catenary curves in blue, parabolas in magenta, **B** particles are equidistant at rest position at the start of the simulation, **C** particle-spring system simulating hanging chains

2014), obtaining the equation $q = k\,L^{-1}(l - l_0)$ where L is the diagonal matrix and q the force densities.

When forces are applied, each particle moves or is fixed. The particles are affected by the internal forces of the springs and the external forces of gravity or applied loads. To find an equilibrium, the system uses Newton's second law ($F = ma$). Every particle of the system has a mass and an unknown acceleration. The system reaches equilibrium when the net force is zero. To help the system converge and reduce the number of iterations required, we can set a tolerance threshold (σ) that allows the system not to reach equilibrium, but to be close enough. For this physical simulation we have used $\sigma = 1$ e−15.

In a system with gravity, we need at least one fixed support for the system to come to rest in equilibrium. For this model, a fixed support has been defined for each point in contact with the ground. By modifying the spring stiffness (k), the loads, the rest length of the springs (l_0), the position of the fixed points and the number of springs, we can control the final shape of our hanging chains. Figure 4 shows that the relationship between spring stiffness and l_0 has a great impact on the type of curve obtained. If the rest lengths $l_0 = 0$, then k will lead to a constant force density (Adriaenssens et al. 2014), obtaining a parabola (Fig. 4B, D).

Figure 4B shows an increase of 5% in the values of l_0 with a constant spring stiffness, while Fig. 4C varies spring stiffness (increments of 20%) with constant

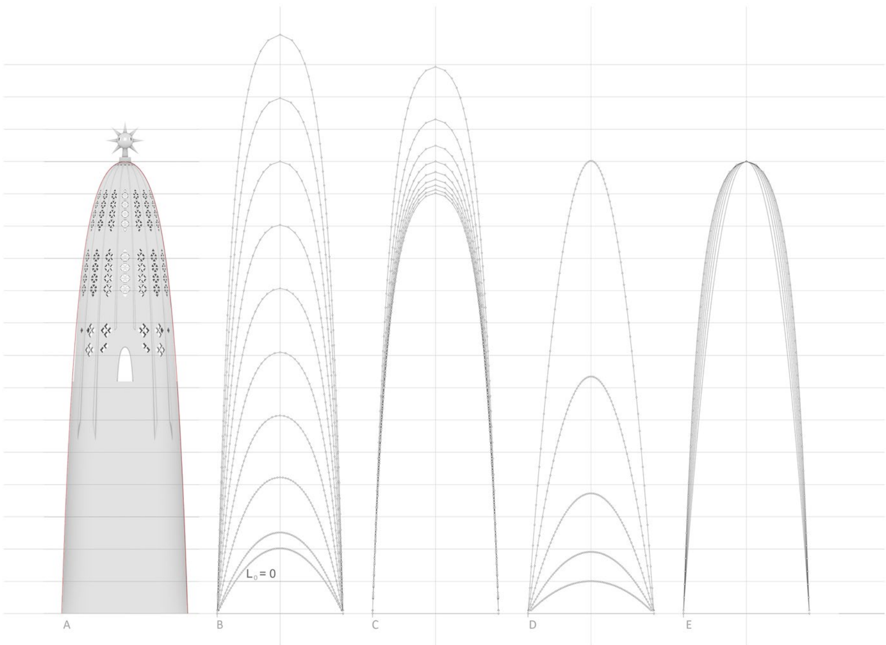


Fig. 4 Relationship between spring stiffness and rest length l_0 **A** final curve, **B** variation of l_0 with a constant high spring stiffness (5%), **C** variations of spring stiffness with constant l_0 (20%), **D** variations of spring stiffness with $l_0 = 0$ (200%), **E** variations of l_0 and spring stiffness with constant height of the chain

l_0. When $l_0 = 0$, we need a high variation of the spring stiffness to obtain important modifications in the hanging chain; in Fig. 4D the increments are 200% of its value. This shows that stiffness of the springs has a lesser impact in the simulation than l_0.

If we want to change the type of curve while maintaining a constant height of the hanging chains, we need to find a balance between the rest lengths and the stiffness values. As Fig. 4E shows, chains are blending from a parabola to a catenary.

Unlike the dynamic relaxation method, when the number of nodes in a particle spring system is modified, the inverted chain undergoes a modification. Figure 5C shows this variation with 40, 60, 80, 100 and 120 particles. If we wanted to emulate the behavior of a dynamic relaxation simulation, so that the number of particles would only influence the resolution of the final curve, we would have to adjust the length of the springs proportionally (Fig. 5D).

It is worth mentioning that when using a particle spring system, the initial position of the particles and springs is irrelevant, except for the length of the springs (Fig. 5E). In this way we could start a simulation from a catenary or a parabola and measure the differences with the final curve.

Finally, to simulate the behavior of the main slabs, internal chains or vertical point loads are introduced (Figs. 6 and 7). Vertical loads generate a greater discontinuity in the chain, especially in the areas near the apex when it tends to be more horizontal (Fig. 6I). When working with internal chains, the degree of continuity of the external chain is greater, even when exaggerating the loads (Fig. 6C).

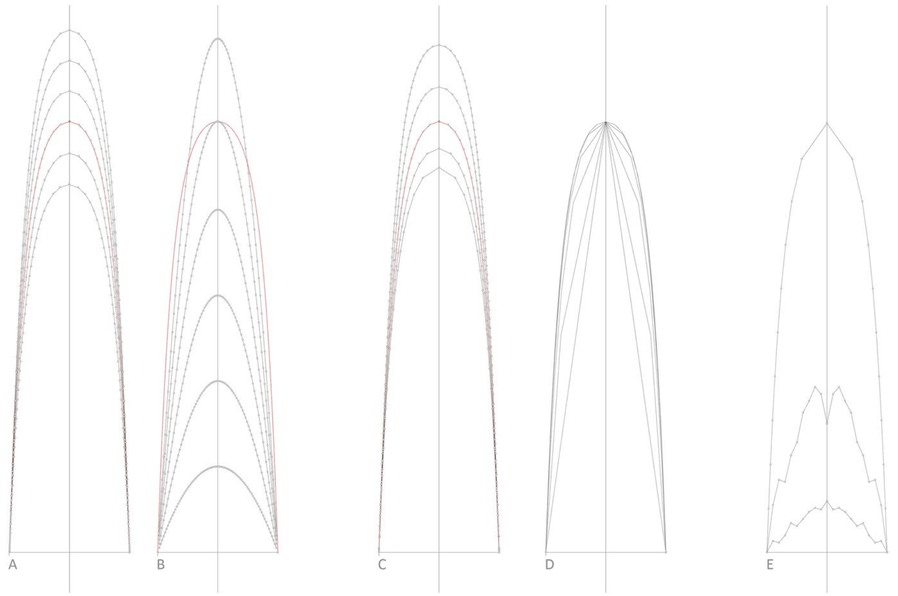


Fig. 5 Weighted catenaries **A** increased uniform loading on particles with high value for l_0, **B** increased uniform loading on particles when $l_0 = 0$ (parabolas), **C** modification of the n number of particles, **D** modification of the n number of particles and length of springs for a constant height, **E** different states of the initial geometry before simulation

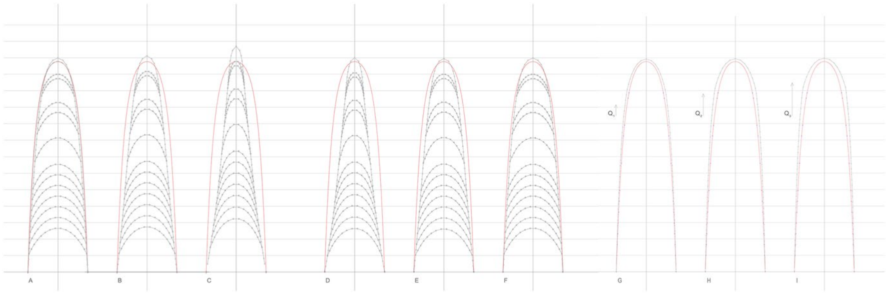


Fig. 6 Modification of the loads on the particles. **A**–**C** Increase of the loads on the internal chains by x.5 and x.50; **D**–**F** decrease of the loads on the external chain by 1/10 and 1/30; **G**–**I** vertical point loads at the points of contact of the facade with the main slabs

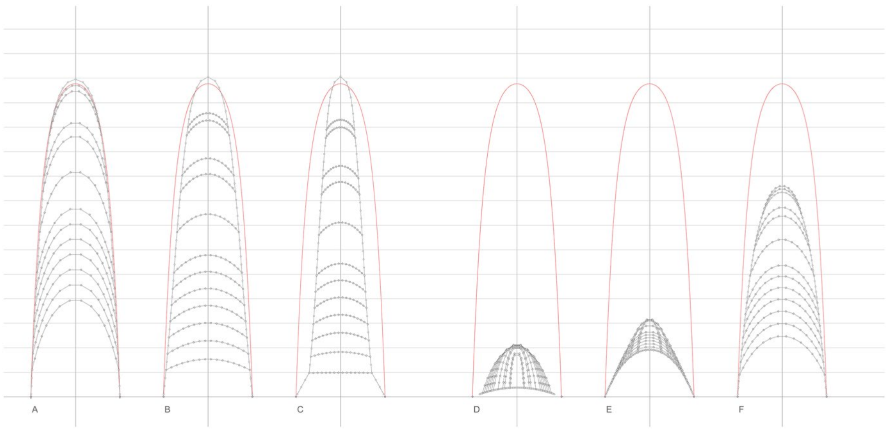


Fig. 7 **A**–**C** Reduction of rest length of the internal chains; **D**–**F** increase of rest length and progressive decrease of stiffness of the main chain, while the other chains are held constant

For this simulation it has been considered that all internal chains have the same length, number of particles and loads. Increasing the number of particles for a chain means increasing the total load, since the loads are applied individually on each particle.

The factor that most influences the deformation of the outer chain is the ratio of the loads applied on the outer chain to the inner chains. The same is true for point loads (Fig. 6). Figure 6A–C shows a progressive increase of the loads on the inner chains. If we increase the loads on the outer chain and compensate the length of the springs, we obtain the reverse effect (Fig. 6D–F). Similarly, if the stiffness of the main chain is very high, its deformation will be lower. As the stiffness decreases and the rest length of the springs increases, the deformation produced by the other chains or loads will be greater (Fig. 7DEF). With a high rest length value and low stiffness in the internal chains, the external weighted chain approaches the shape of a catenary (Fig. 7A).

The surfaces that form the vaults of the Hotel Attraction are generated by the revolution of the catenary curves in relation to their axis of symmetry. This surface should not be confused with the catenoid, a minimal surface that is obtained by the revolution of the catenary in relation to the perpendicular to the catenary's axis of symmetry (Figs. 7 and 8).

Geometry and Structure

The link between geometry and structure and the resulting form that the project takes are inextricably linked in the Hotel Attraction, as in all Gaudí's architecture. This approach to architectural design enjoyed a resurgence during the heyday of the shell structures in the 1950s and 1960s, in the work of architects and engineers such as Candela, Nervi, Torroja or Isler, to name but a few (Faber 1963; Garlock and Billington 2008; Cassinello 2010; Del Blanco García and García Ríos 2018). Others like Frei Otto and Emilio Pérez Piñero (Candela 1972; del Blanco García 2022) also maintained links between geometry and structure in other architectural contexts. Centuries before them, medieval builders had managed to erect great cathedrals that showed the transmission of loads to the ground (Heyman 1995). The Hotel Attraction or the Sagrada Familia in Barcelona are reminiscent of these medieval buildings (Fig. 9).

In his work Gaudí used different types of conical curves, as well as hyperbolic-cosine curves (Huerta 2006b; Samper et al. 2017; González et al. 2018). This led to the geometry of the Hotel Attraction being described by different authors in terms of parabolic curves, ellipses, or catenaries. The superimposition of these different curves onto the original drawings published by Matamala leads us to the conclusion that the arches were in fact drawn by using catenaries (Fig. 10).

On the other hand, several authors have raised the possibility that the vaults may have been generated by quadric surfaces such as ellipsoids, ruled hyperboloids and elliptic paraboloids, or by non-quadric translational surfaces. However, this article shows that the vaults that make up the towers are surfaces generated by the revolution of a catenary curve around its axis. As already

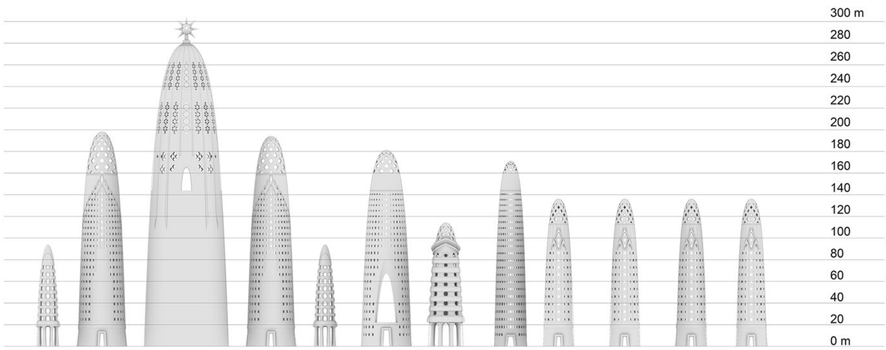


Fig. 8 The 12 towers that make up the skyscraper

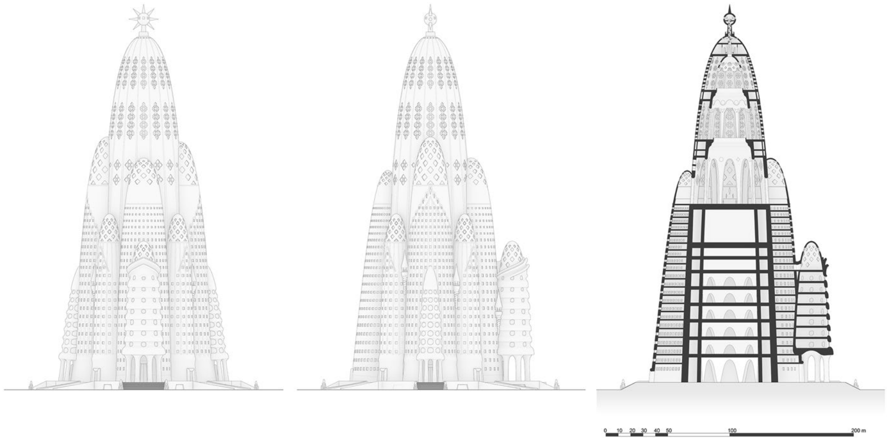


Fig. 9 Elevations and sections of the skyscraper

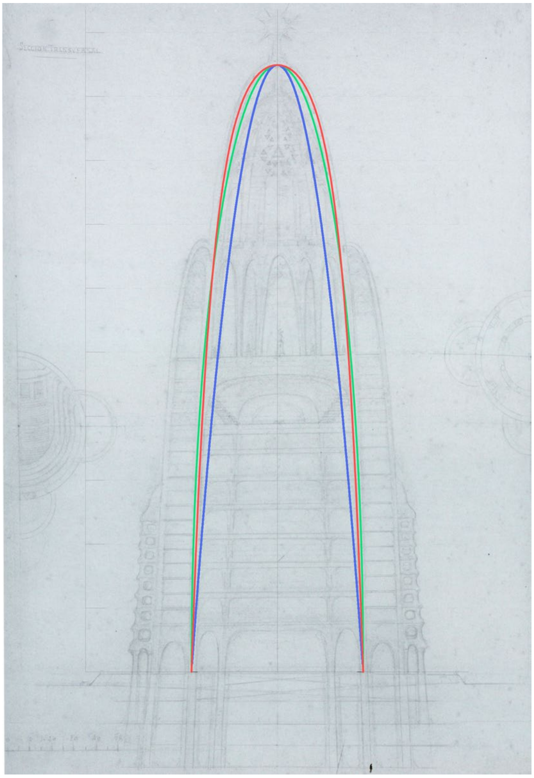


Fig. 10 Comparison between curves: catenary (red), parabola (blue) and ellipse (green). Source of the original sketch: archives of Cátedra Gaudí (Universitat Politécnica de Catalunya) (color figure online)

mentioned, this is not the minimal catenoid surface, which would employ a different axis for the revolution of the curve.

As regards the direction of the axes of the catenaries, we can see that some of these axes are inclined in relation to the horizontal plane. There were initially three hypotheses formulated about the inclination of the axes and the type of surfaces, based on the plan layout (Fig. 11):

The coincidence with the original drawings shows that the second hypothesis, a catenary of revolution with axes inclined in relation to the horizontal plane, was the one used for the design of the skyscraper. This is a solution also favored by Gaudí in other projects.

In this second hypothesis, the intersection of the towers at the perimeter with the great central tower gives rise to warped curves. The point-to-point method was normally used for the plotting of such curves.

The central tower houses a second shell of similar proportions. All towers are connected horizontally by slabs, which may have been used to rigidize the structure (Fig. 12).

Regarding the construction system '[…] it would be adapted to the American system, both in terms of materials and technical organization' (Montaner and Azara 2003: 55).

The configuration of the floor plan is formed by concentric circles that determine the modulation of the project. These serve as the center for the smaller circles that are grouped following a central symmetry (Fig. 13).

The construction of the vaults of such dimensions would generate considerable horizontal forces. The thrust of the central tower could be counterbalanced by the smaller perimeter towers, which lean like buttresses, evoking the classic layout of a medieval cathedral (Fig. 14).

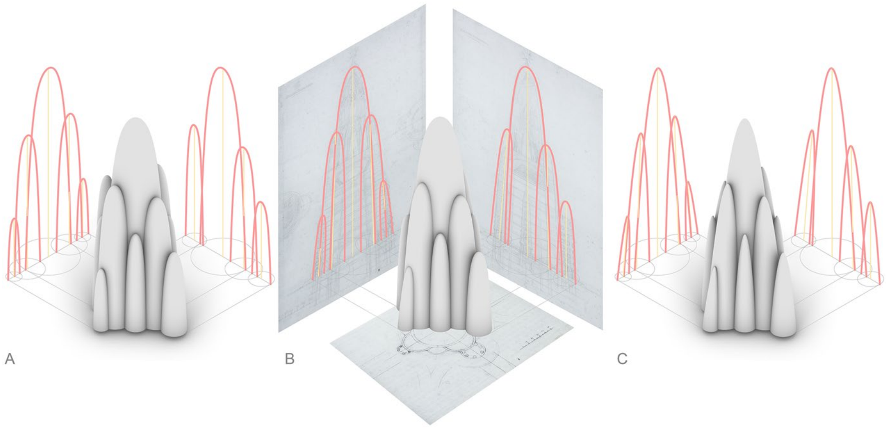
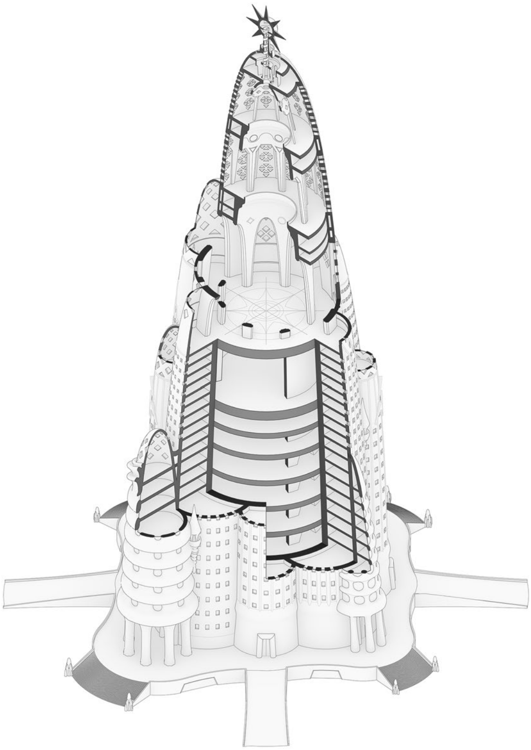


Fig. 11 Hypotheses for definition of the surfaces of the skyscraper. **A** Catenaries of revolution with axes perpendicular to the horizontal plane. **B** Catenaries of revolution with inclined axes. **C** elliptic paraboloids with inclined axes. Source of the original sketches (**B**): archives of Cátedra Gaudí (Universitat Politécnica de Catalunya)

Fig. 12 Isometric section view



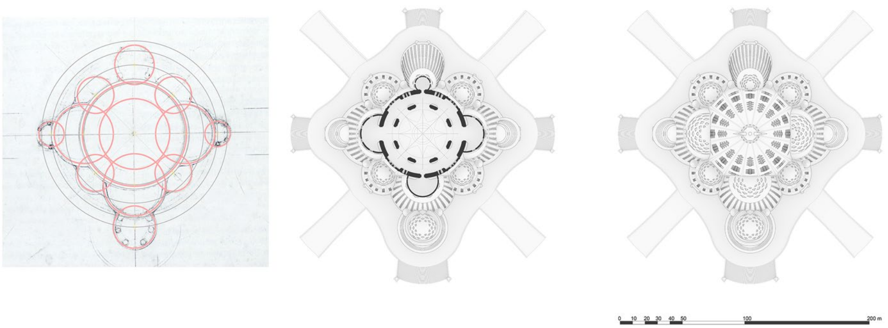


Fig. 13 Geometric scheme, plan of the Hall of America and plan of roof. Source of the original sketch: archives of Cátedra Gaudí (Universitat Politécnica de Catalunya)

The skyscraper resembles a laic cathedral placed upon a multilevel building (Fig. 15), very different from the typology of American vertical buildings and not previously used in Barcelona (De Miguel et al. 2022). In this sense, while the exterior is a fascinating sculpture, the interior, especially the lower half, raises some functional questions.

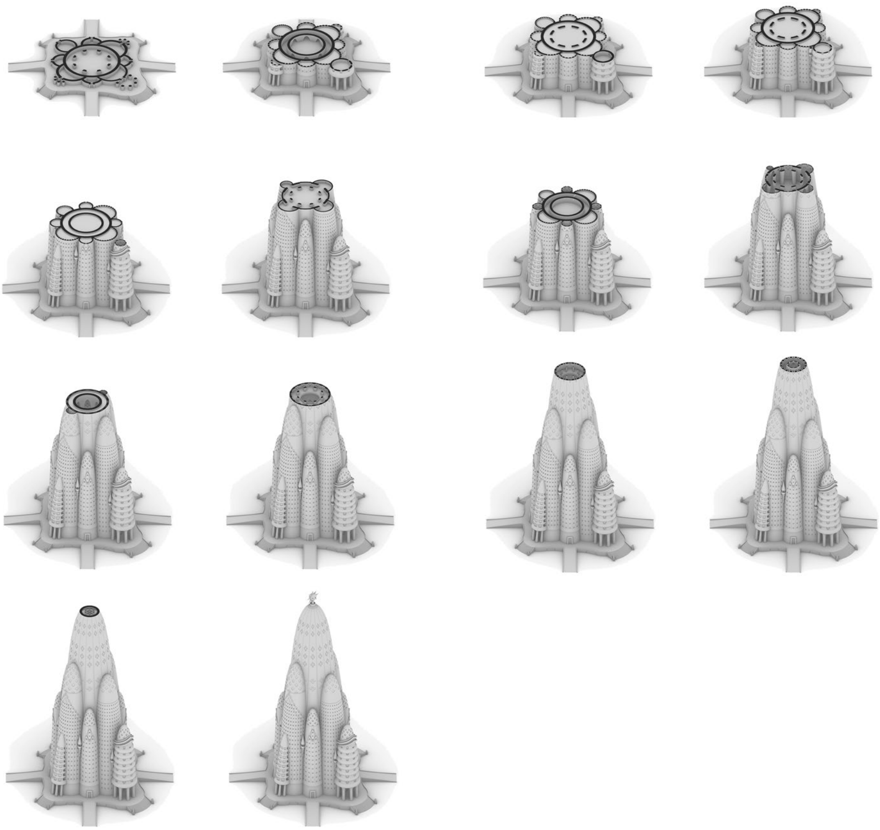


Fig. 14 Horizontal sections of the model

Hypothesis for Closures

The original drawings of the skyscraper show contradictory solutions for the openings for natural light, the rooftop, and the moldings. It appears from the documentation that these elements were not fully defined, possibly because the project was still in its initial phase.

Based on the documentation presented by Matamala, three different solutions that appear in at least one of the drawings have been proposed (Fig. 16):

- The shell has no openings at all, as in the original drawings of the exterior.
- The perforations in the central tower follow the same pattern as the lateral ones.
- The large openings of the central tower are subdivided into smaller ones.

For the definitive model, the third hypothesis has been chosen, since this solution was used by Gaudí in other projects, such as the Sagrada Familia. This seems to be the most rational option, given that it provides control over the

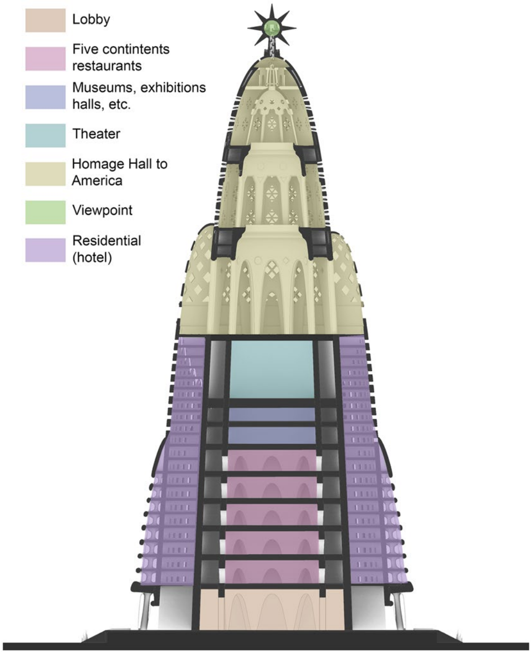


Fig. 15 Vertical section showing the uses and functionality of Hotel Attraction according to the description of Matamala. Image: source

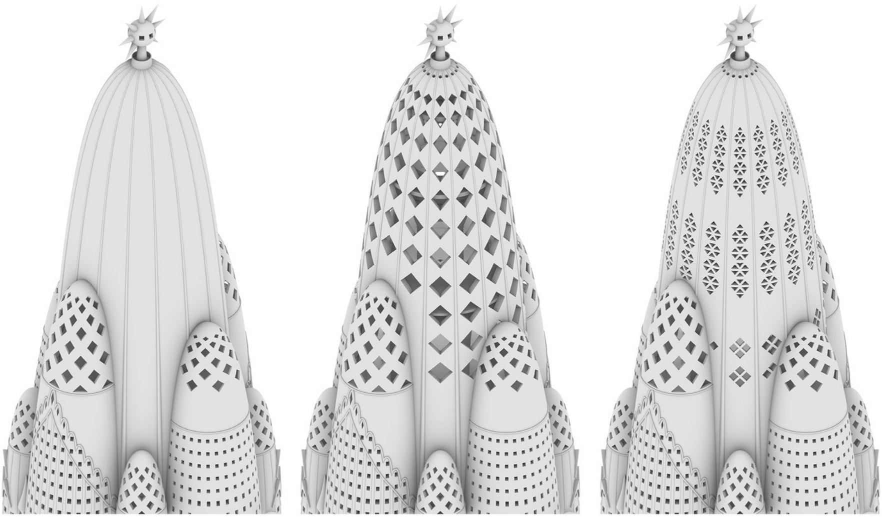


Fig. 16 Three hypotheses for the closure of the skyscraper

scale and allows sunlight to be filtered. While the first hypothesis is the most common in the drawings of the exterior, it would not allow the main space to be illuminated by natural light.

Creation of New Documentation and Export to a Virtual Reality System

Only a few drawings of the skyscraper were published by Matamala, and this is why the new documentation generated by the digital model acquires such importance.

The new documentation incorporates technical plans that provide an overall view of the project and make it easier to analyze Gaudí's work. It could be used by future researchers to examine the project from different perspectives such as structural feasibility, FEM, digital fabrication, bioclimatic studies, etc.

Exporting the model to a real-time rendering engine (UE5) enabled the generation of images that show how the project would appear if it had been built. The objective was not to achieve ultrarealistic photographic images, since the level of specification in the original documentation does not allow this, but to generate images that evoke the ideas as embodied in the initial drawings.

Real-time rendering requires an optimization process that allows a computer or mobile device to be capable of rendering at least 30 frames per second (fps), in order to ensure a smooth immersive experience. In the case of virtual reality, to avoid motion sickness 60 fps is required (Del Blanco García 2021; Wagemann and Martínez 2022), and for this reason the initial NURBS and SubD surfaces were converted into discretized meshes using the Catmull and Clark algorithm for final smoothing (Catmull and Clark 1978). This process necessarily entails a loss of precision, so it is important to distinguish between the two production phases. The generation of plans was carried out using the model made with NURBS and SubD, while the images and immersive scenes were obtained through polygonal meshes (Del Blanco García and García Ríos 2017).

In computational terms, real-time rendering is resource-heavy (Karis et al. 2021; Chen et al. 2022). For this virtual reality model a decision was taken to generate stereoscopic images (Fig. 17), which also allows its use in mobile devices with lower levels of computational power (Aparicio et al. 2022).

The Hotel Attraction is a project without a location. Beyond vague indications that it was located in Manhattan, no site was specified. In 2001, in the wake of the attack that destroyed the twin towers of the World Trade Center, it was proposed to be constructed at Ground Zero, and in 2009 it appeared in the television series *Fringe*. Figure 18 shows image captures of the immersive experience of Manhattan in a visit to the skyscraper using a virtual reality device linked to UE5.

The 3D model of the city divided into sectors was provided by the New York City Planning Department, and the skyscraper was inserted into this model to help us understand how it would relate to its surroundings. It contrasts sharply to the surrounding buildings, owing not only to its proportions but also to its curvilinear forms. Figures 19 and 20 show the two locations selected: first, next to the Empire State Building, a Manhattan skyscraper of similar height with which it would have competed, and second beside the bay, defining the New York skyline.

Fig. 17 Hall of America. Screenshots of scene rendered in real time (16 ms)

Fig. 18 Immersive experience of Manhattan with the skyscraper

Conclusion

The physics-based simulations have proven to be very useful to imitate the procedure

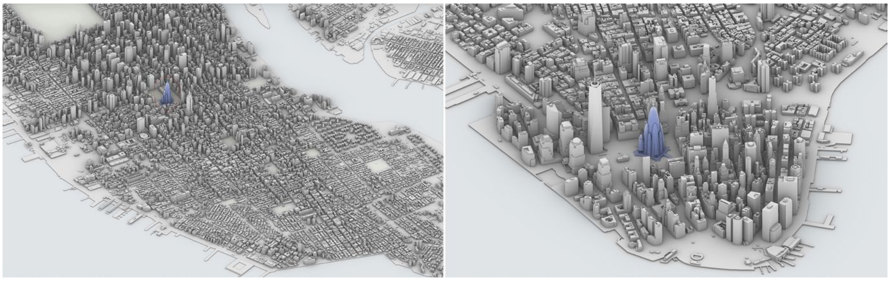


Fig. 19 Two possible locations for the skyscraper in Manhattan

Fig. 20 Elevation of Hotel Attraction next to the Empire State Building

of inverted hanging chains used by Gaudí. In this way it was possible to precisely control the geometry of the curves, avoiding other methods that would deviate from the architect's approach. The advantage of such systems is the iterative nature of the exploration.

The behavior of these digital simulations presents important differences and incorporates new variables compared to the use of scaled models. Controlling the accuracy of these systems is necessary to be able to validate the results obtained. We have been able to verify how the stiffness of the spring has a lesser impact than l_0 (rest length) in the final result. If we want to obtain weighted catenaries close to parabolas, we need to use rest lengths l_0 with values close to 0. If we need to modify the curve to approach a flattened catenary, we need to use higher values of l_0, reducing the stiffness of the springs to compensate and control the applied loads to adjust the height of the hanging chains.

In particle-spring systems we can start from any initial geometry before searching for a dynamic equilibrium. The method makes it possible to study the geometry of this type of curves and to measure the variations from initial curves to the desired ones. This subject requires more research.

Despite the lack of a specific location, there is no doubt that, had it been built, the Hotel Attraction skyscraper would have changed the appearance of Manhattan and maybe the history of American skyscrapers. It would have been made up of soft, organic forms, in contrast to the straight-edged skyscrapers typical of the city. The design for the project possessed sufficient presence to redraw the skyline of New York. The skyscraper is a combination of twelve towers. The organization and development of the digital model of the tower, which serves the symmetry and similitude between the parts of the building, has highlighted that the tower was conceived as a combination of twelve different buildings that mutually intersected. Many questions arise from this observation: besides its symbolic meaning, was it also a strategy to control the design's development, to favor fundraising, the sale of offices and apartments or even the construction stages?

The existence of just one single documented source will always raise doubts as to whether Gaudí really was the author, or whether it was all Matamala's invention. Yet, the skyscraper has been the object of praise from a number of architects, including Rem Koolhaas. It seems unlikely that a project with such characteristics could have been entirely produced by the imagination of a sculptor without any formal training in architecture. As a counterargument, Gaudí had never built a skyscraper, and the Hotel Attraction would have been the tallest in the world at the time. No structural evaluation of the project has ever been carried out, and it remains unknown that it was viable. While stated that the most advanced materials and techniques would be used in the building, the level of detail in the drawings does not allow it to be proven. The drawings and geometry of the project point to a concrete construction based on forces of compression, which implies the use of heavy materials. When completed, the Sagrada Familia in Barcelona will be 172.5 m tall, approximately half the height of the Hotel Attraction.

Acknowledgements All images are by the authors unless otherwise noted. We would like to thank Cátedra Gaudí (Universitat Politécnica de Catalunya) for the authorization to reproduce the images of the project.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. Not applicable.

Data Availability The original data used during the current study are available in the [Cátedra Gaudí at Universitat Politécnica de Catalunya] repository. All data generated or analysed during this study are included in this published article. The data and images generated in the project may be freely reproduced with proper citation.

Code Availability Not applicable.

Declarations

Conflict of Interest Not applicable.

Ethics Approval Not applicable.

Consent to Participate We consent the participation in *The Nexus Network Journal*.

Consent for Publication The *Nexus Network Journal*, a publication owned and published by Kim Williams Books, Turin, Italy, is authorized to publish this article.

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