**PROCEDURA DI VALUTAZIONE COMPARATIVA PER LA COPERTURA DI N. 1 POSTO DI RICERCATORE CON CONTRATTO A TEMPO DETERMINATO IN *TENURE TRACK*, EX ART. 24, DELLA L. 240/2010, COME MODIFICATO DALLA L. 79/2022, DI CONVERSIONE DEL D.L. 36/2022, PER IL GRUPPO SCIENTIFICO DISCIPLINARE 08/CEAR-10, SETTORE SCIENTIFICO-DISCIPLINARE CEAR-10/A, PER IL DIPARTIMENTO DI PROMOZIONE DELLE SCIENZE UMANE E DELLA QUALITÀ DELLA VITADELL'UNIVERSITA' TELEMATICA SAN RAFFAELE ROMA, CORSO DI STUDIO IN PATRIMONIO CULTURALE IN ERA DIGITALE (L-1), INDETTA CON D.R. N. 372 del 24 GIUGNO 2025, IL CUI AVVISO E' STATO PUBBLICATO SULLA GAZZETTA UFFICIALE DELLA REPUBBLICA ITALIANA N° 49 DEL 24 GIUGNO 2025**

**VERBALE N. 3**
**(Discussione orale dei candidati)**

La Commissione giudicatrice della procedura selettiva a n. 1 posto di ricercatore universitario a tempo determinato in *tenure track* (RTT), ai sensi dell'art. 24 della Legge 30 dicembre 2010, n. 240, come modificato dalla legge 29 giugno 2022, n. 79, di conversione, del Decreto Legge 30 aprile 2022, n. 36, per il gruppo scientifico disciplinare 08/CEAR-10, settore scientifico-disciplinare CEAR-10/A, presso il Dipartimento di Promozione delle Scienze Umane e della Qualità della Vita, composta da:

- prof. Marco Giorgio Bevilacqua, Ordinario presso il Dipartimento di Ingegneria dell'Energia, dei Sistemi, del Territorio e delle Costruzioni dell'Università di Pisa;
- prof. Stefano Chiarenza, Ordinario presso il Dipartimento di Promozione delle Scienze Umane e della Qualità della Vita dell'Università Telematica San Raffaele Roma,
- prof.ssa Elena Ippoliti, Ordinario presso il Dipartimento di Storia, Disegno e Restauro dell'Architettura di Sapienza Università di Roma,

si riunisce al completo in presenza, presso il Dipartimento di Promozione delle Scienze e della Qualità della Vita, dell'Università San Raffaele di Roma S.r.l., in Via di Val Cannuta, n. 247, il giorno 10/10/2025, alle ore 8:45, per la discussione dei titoli e delle pubblicazioni scientifiche presentate dai Candidati e per accertare la conoscenza della lingua inglese.
Alle ore **9.00**, in seduta pubblica e seguendo l'elenco reso da parte della Responsabile del procedimento, la Commissione procede all'appello dei Candidati e ne accerta l'identità.
Viene riscontrata la presenza dei Dottori:

1. **AIELLO Laura**
2. **CALDARONE Adriana**
3. **CAMAGNI Flavia**
4. **CONDORELLI Francesca**
5. **LA PLACA Silvia**
6. **LAVORATTI Gaia**
7. **PERTICARINI Maurizio**
8. **PORFIRI Francesca**
9. **ROSSI Maria Laura**

Alle ore 9:15, concluse le operazioni di riconoscimento dei candidati presenti, si procede al sorteggio della prova di lingua inglese. Ciascun candidato sorteggia una tra le tracce predisposte dalla Commissione in numero eccedente rispetto ai presenti (10 tracce allegate al presente verbale).
All'esito del sorteggio le prove di lettura e traduzione estemporanea sono le seguenti:

**AIELLO Laura** - traccia n° 4
**CALDARONE Adriana** - traccia n° 9
**CAMAGNI Flavia** - traccia n° 1
**CONDORELLI Francesca** - traccia n° 3
**LA PLACA Silvia** - traccia n° 8
**LAVORATTI Gaia** - traccia n° 5
**PERTICARINI Maurizio** - traccia n° 6
**PORFIRI Francesca** - traccia n° 10
**ROSSI Maria Laura** - traccia n° 7

Resta esclusa dai sorteggi la traccia n° 2.

Alle ore 9:31, viene invitata a sostenere la discussione IL CANDIDATO n.1. Il Presidente chiede alla Dr.ssa **Laura AIELLO** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "Proportionality in the Architecture of Dom Bellot"(traccia n. 4), viene accertata la conoscenza della lingua inglese.

Alle ore 9:54, viene invitata a sostenere la discussione IL CANDIDATO n.2. Il Presidente chiede alla Dr.ssa **Adriana CALDARONE** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "Reciprocal Frames in Temporary Structures: An Aesthetical and Parametric Investigation" (traccia n.9), viene accertata la conoscenza della lingua inglese.

Alle ore 10:25, viene invitata a sostenere la discussione IL CANDIDATO n.3. Il Presidente chiede alla Dr.ssa **Flavia CAMAGNI** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "Perspective, Cartography and Dynamic Notions: From the Plane Bozzetto to Solid Perspective in Two Examples in Tuscany" (traccia n.1), viene accertata la conoscenza della lingua inglese.

Alle ore 10:49, viene invitata a sostenere la discussione IL CANDIDATO n.4. Il Presidente chiede alla Dr.ssa **Francesca CONDORELLI** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "Leonardo's Vitruvian Man Drawing: A New Interpretation Looking at Leonardo's Geometric Constructions" (traccia n.3), viene accertata la conoscenza della lingua inglese.

Alle ore 11:12, viene invitata a sostenere la discussione IL CANDIDATO n.5. Il Presidente chiede alla Dr.ssa **Silvia LA PLACA** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "Singularities of Perspective in Spain: The 'Other Treatises' on Perspective and their Importance within the European Context" (traccia n. 8), viene accertata la conoscenza della lingua inglese.

Alle ore 11:38 la Commissione sospende i lavori e li riprende alle ore 11:57.

Alle ore 11:57, viene invitata a sostenere la discussione IL CANDIDATO n.6. Il Presidente chiede alla Dr.ssa **Gaia LAVORATTI** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "Folded Compositions in Architecture: Spatial Properties and Materials" (traccia n. 5), viene accertata la conoscenza della lingua inglese.

Alle ore 12:26, viene invitata a sostenere la discussione IL CANDIDATO n.7. Il Presidente chiede al Dr. **Maurizio PERTICARINI** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "Life, Architecture, Mathematics, and the Fourth Dimension" (traccia n. 6), viene accertata la conoscenza della lingua inglese.

Alle ore 12:59, viene invitata a sostenere la discussione IL CANDIDATO n.8. Il Presidente chiede alla Dr.ssa **Francesca PORFIRI** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "The Lightfall and the Symbolic Function of the Hyperbolic Paraboloid Surface" (traccia n. 10), viene accertata la conoscenza della lingua inglese.

Alle ore 13:24, viene invitata a sostenere la discussione IL CANDIDATO n.9. Il Presidente chiede alla Dr.ssa **Maria Laura ROSSI** di esporre brevemente il percorso formativo, di illustrare i propri titoli ed i propri interessi di ricerca, nonché di indicare la consistenza del suo contributo alla ricerca nel settore scientifico disciplinare del Disegno. In seguito, mediante la lettura e la traduzione dell'opera dal Titolo "Projecting an Architectural Perspective: Euclidean Propositions and Common Practices at Gonc¸a lves Sena's Workshop" (traccia n. 7), viene accertata la conoscenza della lingua inglese.

La discussione orale dei titoli e delle pubblicazioni e l'accertamento della conoscenza della lingua straniera indicata nel bando hanno termine alle ore 13:55.

In Seguito, la Commissione procede ad analizzare tutta la documentazione presentata, così da poter attribuire un punteggio ai titoli, alle pubblicazioni ed alla produzione scientifica dei Candidati, sulla base dei criteri già dettagliati nella riunione preliminare.

Alle ore 16:20, la seduta è conclusa e il presente verbale viene letto, approvato e sottoscritto e trasmesso alla Responsabile del Procedimento, dr.ssa Daiana Rotondi, per la pubblicizzazione sul sito web dell'Ateneo.

La Commissione sospende i lavori e decide di riconvocarsi in modalità telematica lunedì 13 ottobre 2025, alle ore 18:30, per l'attribuzione dei punteggi ai candidati e per la definizione della graduatoria finale di merito.

LA COMMISSIONE:

- Prof. Stefano Chiarenza - Presidente
- Prof. Marco Giorgio Bevilacqua - Membro
- Prof.ssa Elena Ippoliti - Segretario

**PROCEDURA DI VALUTAZIONE COMPARATIVA PER LA COPERTURA DI N. 1 POSTO DI RICERCATORE CON CONTRATTO A TEMPO DETERMINATO IN *TENURE TRACK*, EX ART. 24, COMMA 3, DELLA L. 240/2010, COME MODIFICATO DALLA L. 79/2022, DI CONVERSIONE DEL D.L. 36/2022, PER IL GRUPPO SCIENTIFICO DISCIPLINARE 08/CEAR-10 "DISEGNO", SETTORE SCIENTIFICO-DISCIPLINARE CEAR-10/A "DISEGNO", PER IL DIPARTIMENTO DI PROMOZIONE DELLE SCIENZE UMANE E DELLA QUALITA' DELLA VITA DELL'UNIVERSITA' TELEMATICA SAN RAFFAELE ROMA, CORSO DI STUDIO TRIENNALE IN PATRIMONIO CULTURALE IN ERA DIGITALE (L-1), INDETTA CON D.R. N. 372 DEL 24 GIUGNO 2025, PUBBLICATO SULLA GAZZETTA UFFICIALE DELLA REPUBBLICA ITALIANA, 4^ SERIE SPECIALE – CONCORSI ED ESAMI -, N. 49 DEL 24 GIUGNO 2025: colloquio orale del 10 OTTOBRE 2025, ore 09.00**

## CANDIDATI AMMESSI AL COLLOQUIO ORALE

| N. | CANDIDATO | LUOGO E DATA DI NASCITA | DOCUMENTO DI RICONOSCIMENTO | FIRMA |
|---|---|---|---|---|
| 1 | AIELLO LAURA | CATANZARO 28/02/1979 | PATENTE U1X692483J | Laura Aiello |
| 2 | CALDARONE ADRIANA | TERLIZZI 11/03/1987 | CARTA IDENTITA' CA88590MV | Adriana Caldarone |
| 3 | CAMAGNI FLAVIA | ROMA 21/03/1990 | PATENTE U1957185 6X | Flavia Camagni |
| 4 | CONDORELLI FRANCESCA | SALERNO 1/5/1990 | CI AU5751549 | Francesca Condorelli |
| 5 | LA PLACA SILVIA | FIRENZE 23/08/1993 | CDI CA44838OY | [illegible] |
| 6 | LAVORATTI GAIA | PESCIA 25/09/1980 | C.I. AY1179534 | Gaia Lavoratti |

| | | | | |
|---|---|---|---|---|
| 7 | PERTICARINI MAURIZIO | [illegible] 02/07/1988 | C.I. N° CA83704JY | |
| 8 | PORFIRI FRANCESCA | ROMA 22/12/1984 | C.I. n CA67602NF | |
| 9 | ROSSI MARIA LAURA | RIETI 18/10/1988 | C.I. n. CA84078FU | |

Roma, lì 9 ottobre 2025

La Commissione:

Prof. Stefano Chiarenza – Presidente
Prof. Marco Giorgio Bevilacqua – Membro
Prof.ssa Elena Ippoliti - Segretario

Camagni

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NEXUS NETWORK JOURNAL
Architecture and Mathematics

RESEARCH

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# Perspective, Cartography and Dynamic Notions: From the Plane *Bozzetto* to Solid Perspective in Two Examples in Tuscany

**Nevena Radojević**[1]

Published online: 12 May 2016


**Abstract** In order to create a perspective drawing on a curved surface, the quadraturista had to face, in addition to the flat perspective drawing issues, also the ones related to the mapping of the three dimensional surface. In literature we can find two methodologically different approaches related to the flat design transposition procedures onto the curved surface: indirect and direct method. The indirect one, partially described by Vignola, is based on the use of pre-designed cartoons on the ground. The direct one, described by Andrea Pozzo, is based on the direct projection of a flat grid onto the curved surface. Both the ceiling painting of the Church of San Matteo in Pisa and the parietal one of the Church of S. Caterina in Livorno show, even if observed from the privileged viewpoints, some irregularities. These irregularities, as we are going to show, are actually the consequences of the method applied for the transposition of the flat drawings onto the curved surfaces.

**Keywords** Linear perspective · Architectural perspective · Quadraturismo · Illusionistic painting on the vault surface · 3d survey · Panoramic imaging · Three-dimensional restitution · Cartography · Surface development · Bozzetto · Field of view · Geometry

## Introduction

In order to create a perspective drawing on a curved surface (both parietal and ceiling), the artist needs to face, in addition to the linear perspective construction issues, also the ones related to the mapping of the three-dimensional surface. The transposition of the flat preparatory perspective drawing or *bozzetto* onto the vault

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surface is always done with the aid of the grid or *quadrettatura*. Once the deformed grid is obtained on the curved surface, the preparatory drawing should only be fitted into that grid.

Both the ceiling painting of the Church of San Matteo in Pisa and the parietal painting of the Church of Santa Caterina in Livorno show some drawing deformations, even if seen from the privileged viewpoints. These irregularities, as we are going to show, are consequences of the method applied for the transposition of the flat drawings onto the curved surfaces. The transposition method, in both examples, is not based on exact projective principles, or more precisely, the mapping of the vault (by the aid of central projection of the flat grid) does not occur directly on the actual vault, but on a scaled and simplified model. The mapping procedure of the actual vault, instead, comprises the design transposition onto the vault from the developed, actual size cartoons (done by enlargement of the scale ones).

In literature we can find two methodologically different approaches related to grid transformation procedures that we could define as the indirect and direct methods. In his famous treatise *Perspectiva pictorum et architectorum*, Andrea Pozzo explained the method he used for the transposition of the flat drawing onto the vaulted surface in the Church of St. Ignatius in Rome, that consists of a direct central projection from the privileged viewpoint[1] of the grid placed onto the vault impost onto the vault. By applying this direct method the eventual drawing deformations produced by the irregularities of the surface itself would not be visible in the painting when seen from the privileged viewpoint, as Pozzo also observed (Pozzo 1693). Another method, the indirect one, is given by Jacopo Barozzi da Vignola and is based on the use of pre-designed cartoons on the ground (Vignola 1583; Troili 1672; Bibiena 1711).

Vaulted surfaces, as we know from practice, are never perfectly regular.[2] If the transposition method of the straight lines is direct from the viewpoint onto the surface, the irregularities of the vault donot influence the final visual result, whilst if the method is indirect (by the aid of cartoons for instance) these irregularities become evident on the painting and visible even from the privileged viewpoint. Real scale drawings that need to be transferred onto the vaults are done, according to the indirect method, by the enlargement of the cartoons designed by the aid of scaled models. These scaled models never perfectly correspond to the real surfaces and the discrepancy between the two different geometries produces errors.

Another issue is the uniqueness of the viewpoint for which the paintings were intended. As seen in some other examples, the viewpoint was not necessarily always intended to be static by painters, especially when the picture plane (quadro) is vertical and the observer is free to move along it (Bartoli 2015). However, as far as we are concerned, this argument was never discussed in literature.

[1] The "privileged viewpoint" or just a "viewpoint" is the center of projection of an imaginary spatial configuration onto the surface. The depicted illusory space appears as it should when seen from this point.

[2] The vaults are rarely regular geometries as the literature usually describes them. Their form is a result of the complex constructive processes.

Mun estratto

(2)

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Architecture and Mathematics

RESEARCH

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# Baroque Oval Churches: Innovative Geometrical Patterns in Early Modern Sacred Architecture

Sylvie Duvernoy[1]

Published online: 20 May 2015


**Abstract** Italian religious architecture of the late Cinquecento is marked by an innovative interpretation of the canon of the central plan that generates a new type of Baroque church: the elongated central space. By building oval churches covered with oval domes, Jacopo Barozzi da Vignola (1507–1573) introduced a new pattern into the architectural shape grammar. The geometry of the oval figure gracefully combines the theoretical concept of cosmic centrality and the pragmatic necessities of liturgical linearity. However it raises a number of design problems for which architects devised various and inventive solutions. The comparison of various churches dating back to no later than the end of the Seicento, highlights the diversity of all the projects. Although every church is unique in its layout, design, features and decoration, all oval churches propose similar challenges to their designer, the most important of which are the choice of the geometrical pattern, the dome, and the façade.

**Keywords** Oval churches · Italian baroque · Religious architecture · Central space

## Introduction: the Concept of Centrality

Sacred architecture of the Italian Renaissance is marked by the dissemination of a special kind of building: the centrally planned church.

The morphological features of the centrally planned church are quite simple and therefore recognizable. They differ from other models such as the basilica type or Latin cross type in the sense that the inner space does not expand longitudinally but

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radially, and in concentric rings, from a centre which is the core of the sacred space. Either circular, square or polygonal in plan, the central area is usually covered with a dome, and is dedicated to hosting the worshipping congregation. In centrally planned churches, the dome rises over the heads (and souls) of the worshippers, thus creating a different spatial relationship between the single individual and the house of God.

The spread of centrally planned churches from the second half of the fifteenth century onward, is part of the more general renaissance of Classical culture as a whole, evidence of which is found in every field of sciences and arts. Following the example of the then recently rediscovered architectural treatise by Vitruvius, *De Architectura Libri Decem* (Ten Books On Architecture, c.15 B.C.),[1] Leon Battista Alberti (1404–1472) wrote his own treatise entitled *De Re Aedificatoria* (On The Art Of Building In Ten Books, c.1450): the first of the many literary works on architectural theory that would be produced in the centuries that followed. Although similar to Vitruvius's manuscript in its structure and purpose, Alberti's text is unquestionably a modern text, in which design principles are formulated according to the then current principles of Humanism. Vitruvius's and Alberti's theories on sacred buildings, for instance, differ quite sharply. While in his book on temples Vitruvius only mentions round temples in passing, Alberti recommends nine possible geometrical diagrams for temple design, six of which are circular or polygonal, and only three of which are rectangular. The square, the hexagon, the octagon, decagon and dodecagon are the recommended polygonal shapes, and he insists on the fact that their angles must be precisely drawn, equal to one another; otherwise they won't be regular and inscribed in a circle. The circle seems therefore to be the ultimate reference, since it is—Alberti states—the favourite shape of nature.

One of the most famous early examples of a centrally planned church is Santa Maria delle Carceri, designed by Giuliano da Sangallo (1445–1516), built in Prato (Tuscany) in 1485. A composition of squares, circles, cube and sphere, its geometrical diagram is the paradigm of symbolic solid geometry. In the same years, around 1489, Leonardo da Vinci (1452–1519) filled many pages of his sketchbooks with drawings and studies on the theme of the centralized church, exploring several different geometrical options, varying the basic polygon used in plan, going from the square to the octagon, and the circle. All plan diagrams are completed by a perspective view of the possible volume that can be built from the plan sketch (Xavier 2008). Donato Bramante's (1444–1514) proposal for the new church of San Pietro in Rome is directly connected to Leonardo's studies. Leonardo and Bramante were both at the Milanese Court of the Duke Ludovico Sforza *Il Moro* at the end of the fifteenth century and they most probably collaborated while studying new models for church design. The influence of this research extends to most of the centralized churches that were built in the first half of the sixteenth century. The church of Santa Maria della Consolazione in Todi (Umbria), on which construction

[1] *De Architectura Libri Decem*, written around 15 B.C. and dedicated to Emperor Augustus is the only theoretical and technical treatise on architecture that has come down to us from Classical antiquity. The latest English translation of Vitruvius' text is *On Architecture*, translated by Richard Schofield (Vitruvius 2009).

Corradelli

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NEXUS NETWORK JOURNAL
Architecture and Mathematics

RESEARCH

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# Leonardo's Vitruvian Man Drawing: A New Interpretation Looking at Leonardo's Geometric Constructions

**Vitor Murtinho**[1]

Published online: 9 April 2015


**Abstract** Generally speaking, today's scientific community considers that the famous figure drawn by Leonardo da Vinci at the end of the fifteenth century was made using the Golden ratio. More specifically, the relationship established between the circle's diameter and the side of the square is a consequence of the geometric relationship probably discovered by Euclid, but made famous by Luca Pacioli in his *De Divina proportione*. Aware of the close working relationship between Leonardo and Pacioli, namely in the writing of this last book, the theory that establishes a close relationship between these two figures, making use of this remarkable mathematical relationship, has gained credibility. In fact, the use of the *Divina proporzione*, despite being a very stimulating construction on an intellectual level, presents too great a margin of error, especially for such a competent geometrician as Leonardo da Vinci was. For that reason, the relationship between these two figures (square and circle) is grounded on a much simpler geometric relationship than the one found at the base of the definition, for instance, of Le Corbusier's *Modulor*.

**Keywords** Leonardo da Vinci · Vitruvian man · Vesica piscis · Golden number · Proportion

## Introduction

*No human investigation may claim to be a true science if it has not passed through mathematical demonstrations, and if you say that the sciences that begin and end in the mind exhibit truth, this cannot be allowed, but must be*

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Birkhäuser

*denied for many reasons, above all because such mental discourses do not involve experience, without which nothing can be achieved with certainty.*
(Leonardo 1989, p. 14)

The Vitruvian man is, undoubtedly, Leonardo da Vinci's most famous and widely reproduced folio (Fig. 1). This representation, which objectively reflects the human body's proportional basis, is historically associated with the Roman architect Marcus Vitruvius Pollio, who explained the principle in his book *De Architectura* at the beginning of the first century AD. If this drawing objectively represents the Leonardian reflection on the canon that apparently regulates the different parts of the human body, in reality this figuration has been recurrently used to illustrate the Renaissance idea of man as a symbolic microcosm, thus praising his role as the centre of the universe.

It is certain that this fascination with the human body is transversal throughout history, and that it probably had its beginning when, in the caves of Pech Merle (about 10,000 BC) in France, man indelibly left the mark of his footstep and

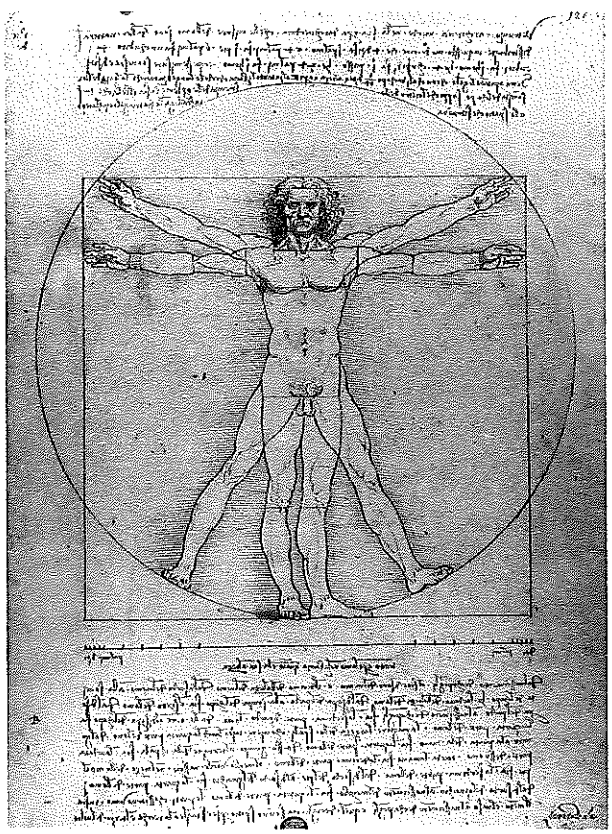

**Fig. 1** Leonardo da Vinci, study of human proportions in the manner of Vitruvius (c. 1490), Gallerie dell'Accademia, Gabinetto dei Disegno e Stampe, n. 228, Venice

fingerprint. Unwittingly or in a conscious manner, he left a record and gaugeable metric base against which to determine, exactly, some of the dimensions of men from that pre-historic age (Fig. 2). There was at the time no idealized or stable system regarding the dimensioning of things in their relation with humans, but this concern can be found a few centuries later in the unfolding of the Egyptian civilization, with the adoption of metrological systems (Badawy 1965, pp. 36–38) as well as graphic and spatial modulations in the definition of art in general and architecture in particular.[1] During the Greek period we can already find a stable use of measurement units taken from human body parts, thus shedding light on Protagoras' precept that man is the measure of all things. In parallel, and in the field with more of an artistic calling, Polykleitos develops a written canon that allegedly demonstrates the harmonious principle between the parts as well as between them and the whole of the human body,[2] and he would eventually materialize this rule in the celebrated statue named Doryphoros (Fig. 3).[3] For this reason, one is not surprised by the confident and very concrete manner in which Vitruvius defines, through his *homo bene figuratus*, a rigorous proportional base for the human figure. In particular, he defines the metrical foundations from the finger, palm, foot, and cubit and characterizes the relationship between these different parts.[4] Zealously, at the base of his Vitruvian man drawing and certainly bearing the Roman architect's text in mind, Leonardo graphically materializes a scale that allows the foot and palm measurements to be identified, on both sides of the representation, and they somehow establish a graduated system against which to measure the real man and his presented figuration. This probably becomes one of the first presentations where

[1] Among the extensive bibliography on Egyptian art about modular diagrams and Egyptian dimensions cf., for instance, Ruiz de la Rosa (1987, pp. 60–74) or Rossi (2004, pp. 2–56); a classic source on the relationship between architecture and human anatomy is always Schaller de Lubicz (1949).

[2] Given that the book is missing, the descriptions that come closer to what Polykleitos' *canon* would be, with eminently anthropomorphic characteristics of comparison between parts of the human body, are the ones referred to by Galen in Placitis Hippocratis et Platonis. Galen's most important quote is mentioned by Torrini (2009, p. 36).

[3] For a more encompassing approach on the relation between the human body and the metric systems cf. Murtinho (2006, pp. 180–191). In the specific case of the proportional base at the origin of the Doryphoros statue cf., for instance, the analysis conducted by Pierre Gros on the copy existing in Naples which corresponds to the most widely celebrated reproduction using Polykleitos' *canon*. This analysis intends to confirm the principle that the various parts of the human body, starting with the smallest, are obtained, according to Polykleitos, from the relation of dynamic squares whose common element is the fact that the side of one corresponds to the diagonal value of another, and so on. Architects often used this proportional relation, historically very common, in different historic periods. One example of its application can be found in Villard de Honnecourt's notorious medieval album, the cloister design method, where the relation between covered and uncovered parts is regulated by the proportion founded on the square root of two principle, which technically corresponds to the *ad quadratum* construction. On Polykleitos cf. Gros (2006, pp. 81–83); on Villard and the *ad quadratum* construction cf. the first article cited in this note.

[4] "And further, as the foot is one sixth of man's height, the height of the body as expressed in number of feet being limited to six, they held that this was the perfect number, and observed that the cubit consisted of six palms or twenty-four fingers. (...) They found their authority for this in the foot. For if we take two palms from the cubit, there remains the foot of four palms; but the palm contains four fingers." (Vitruvius 1914, p. 74). For a better understanding of the measures according to Vitruvius, we recommend reading Cunha (2003, pp. 22–24).

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# Proportionality in the Architecture of Dom Bellot

**Liz Dewitte**[1]

Published online: 9 April 2015


**Abstract** This paper explores the proportional system of the Benedictine monk and architect Dom Paul Bellot o.s.b. (Ordo Sancti Benedicti). A review of the geometrical study of the chapel of the former Augustinian College in Eindhoven (NL), built by Dom Bellot in 1922–1925 is presented. An analysis of the cross-section of this chapel shows the use of the Golden Section angle of almost 60° in combination with triangular tracing. Dom Bellot used this set angle to construct harmonic geometry in an effort to create universal beauty and to divide greater parts into smaller parts in a harmonious way. Dom Bellot also used his Golden Section angle to build his diverse arches in the chapel.

## Introduction

Dom Paul Bellot (1876–1944) was an influential French Benedictine monk and architect in the first half of the twentieth century. He made strong and powerful religious architecture arguing that architecture should be both useful and beautiful. Rejecting the modernist view of form following function, Dom Bellot's philosophy was that if something was functional, it must also surpass our every day expectations and delight the senses and the mind.

> Le beau consiste *dans* une juste *proportion des choses*, c' est-à-dire une *disposition*, un *ordre interne* qui est pour *l' esprit*, qui contemple derrière les impressions sensibles, *harmonie* et *clarité*. (Bellot 1948, p. 101; Willis 1994).
>
> *According to Dom Bellot, true beauty lies in the right proportion of things, an internal order of the spirit, which acts on our senses, with harmony and clarity* [translation by the author].

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Dom Bellot also wrote: "L'apprentissage de la vie monastique, fort heureusement, me permit de me livrer vraiment à la réflexion, de me dégager de la fascination des forms anciennes et de découvrir, pour mon profit, l'âme même de la tradition, son courant vital, et, en lui, les principes perdurables de l'art et du gout". [The monastic life, fortunately, enabled me to reflect on and to clear my fascination for ancient forms and discover, for my benefit, the soul of tradition, its vital power, and in it, the sustaining principles of art and style (translation by the author)] (Bellot 1948, p. 43; Willis 1994).

This paper considers the question: which generating principle of architectural proportion did Dom Bellot exactly found? Did he—as Golden Section believer—really build up his geometrical schemes according to this irrational ratio 1.618034(φ)? This paper wants to prove that his discoveries of the Golden Section are actually based on the rational ratios 5:3 (1.666...), 4:3 (1.333...) and 1:2.

An additional component of this review is the geometrical study of the chapel of the former Augustinian College in Eindhoven. This study was carried out from the perspective of an architect-designer. This study is based on the conditions indicated in the paper *Under Siege: The Golden Mean in Architecture* by M. J. Ostwald. This paper says that proportional analysis should only be undertaken where there is clear, visible evidence that the architect was aware of the Golden Mean (Ostwald 2002). This study would also refers to the paper *Contra Divinam Proportionem.* (Frascari et al. 1998) which says that during antiquity ratios were used to manifest incommensurable entities. These approximations were judged perfectly acceptable.

## Biography

The life of Dom Bellot is described in detail in the introduction of the book *Propos d'un Bâtisseur du bon Dieu* (Bellot 1948, 13–25), and in *Dom Bellot Moine-Architecte 1876–1944* (Culot et al. 1996, pp. 29–79) (Fig. 1).

Paul Bellot was the eldest son of an architect-surveyor, who was an admirer of the French architect and theorist, Viollet-le-Duc (1959). From 1894 to 1900 he studied architecture at the *Ecole des Beaux-Arts,* in Paris. In 1902 he joined the Benedictine community in Solesmes. He had to live according to the rules of St.

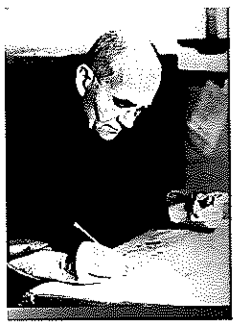

**Fig. 1** Dom Paul Bellot. In August 1928, Bellot left Oosterhout and continued his practice at *l'Abbey Saint-Paul de Wisques*, in France. He also worked on the launch of "l'Arche", a group of French artists and architects (also the Perret brothers) who came together in 1919 to make a Christian art reform in France. [Guéné 2000; Pouls 2002]

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# Folded Compositions in Architecture: Spatial Properties and Materials

**Mauro Chiarella · Rodrigo García Alvarado**

Published online: 10 December 2014


**Abstract** The two-dimensional unfolding of three-dimensional volumes allows architectural design and production methods to be rethought in a creative way. This paper reviews spatial and material properties of folded compositions in architecture, through a conceptual proposal based on professional and pedagogic experiences as well as new technologies for geometrical programming and digital fabrication, tested in five alternatives for one case study. The continuous and dynamic two-dimensional projection of a three-dimensional spatial situation provides a geometric relationship between the surface and volumetric configuration of a design, thus enabling a mathematical and operative connection between conditions of perception and production. The material expression of these configurations establishes a significant link between the conceptualisation of the design form, its geometric digital generation, its physical fabrication and overall appearance in a manner analogous to the design process used. The combination of folded compositions with the new technologies available further strengthens their potential, which embraces the fluid nature of human activity with continuous forms and delicately intricate geometries.

**Keywords** Design analysis · Structural systems · Geometry · Transformations · Folded compositions · Form making

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## Introduction

Folded compositions in architecture allow design and production methods to be rethought in a creative way. The designer moves away from the prevalence and, to a certain degree, the historical determinism of graphical architectural thinking based on descriptive geometry, which has for many years enjoyed almost total stylistic control over the objects built. The continuous two-dimensional projection of a three-dimensional spatial situation provides an alternative geometric relationship between the surface and volumetric configuration of a design, thus enabling an operative connection between conditions of perception and production. As evidenced in the usual paper folding exercises, applied also by Josef Albers at the Bauhaus (Buri and Wein 2010), as well as in recent experiences with ruched wood in the Pavilion ICD/ ITKE (Knippers and Menges 2011) or with metal sheets through the system Robofold (Peters 2011). The material expression of these configurations displays the capacity to control production methods and physically explore their spatial development. While this process also reveals aspects of scale and construction that limit the range of models produced, it establishes an important connection between the conceptualisation of the design form, its geometric generation, its physical fabrication and its overall appearance.

The potential of folded compositions in architecture has been exhibited in some of buildings by contemporary architects, (such as: Valleaceron Chapel, Spain by Sancho-Madridejos; Yokohama International Port Terminal by Foreign Office Architects; Maison Folie de Wazemmes by NOX; and Tod's Omotesando by Toyo Ito), all of which claim to have used folding design processes (James 2008; Chiarella 2009), developing new spatial and material configurations (Fig. 1).

The possibilities of folded compositions in architecture have also been explored and defined in experimental exercises and diverse teaching activities (Vyzoviti 2003, 2006; Saito et al. 2009; Tachi 2010; Chiarella 2011). However, the spatial and material properties of this method have not been fully explored in terms of the possible production processes for a more generalised application. If folding compositions are to become more widespread in architecture, the potentials and conditions of the method must be characterised so that it can be integrated into both teaching and professional practice. This article, based on activities from the research project FONDECYT 3110025, sets out a relationship between the spatial and material properties of folded compositions in architecture, illustrated in strategies developed with parametric programming and digital fabrication, in order to foster the application and use of these new design technologies.

## Spatial Properties of Folded Compositions

Folded compositions can be defined as the transformation of a physical form, to double a flat structure (according to the Merriam-Webster Dictionary), as can be seen from the primary experiences (Buri and Weim 2010), to contemporary (Iwamoto 2009; Knippers and Menges 2011; Peters 2011). However, they also offer wider possibilities in the spatial and material elaboration of building design, from

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# Life, Architecture, Mathematics, and the Fourth Dimension

**Snezana Lawrence**

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**Abstract** The fourth dimension, whilst contemplated from as far back as antiquity, was only studied in mathematics from the nineteenth century. Here we trace the history of these investigations, and place them in the context of their manifestations in architecture, whether real or imagined. As we take a look at the social milieu within which the study of the fourth dimension flourished, in the nineteenth and early twentieth centuries, we investigate the biographies and works of the protagonists, and note that the study of the fourth dimension, and dimensionality itself, was strongly coloured by considerations of ethics and even religiosity. Finally we look at a few examples of architecture which offer different interpretations of the fourth dimension.

**Keywords** Polytopes Polyhedra · Fourth dimension · Dimensionality · Schläfli symbol · Tesseract · Euler's characteristics · Spiritualism · Theosophy · Antroposophy · Flatland

## Introduction

When searching for links between mathematics and architecture that are difficult to describe, we stumble upon the higher dimensions: we have few options for understanding this concept, and even fewer possibilities of materializing it in an architectural creation. Perhaps this feeling of being 'stuck' in our three-dimensional world is somehow alleviated by the invention of the parallel e-universe and the possible architectures of our increasingly networked digital world and the internet. Nineteenth-century researchers grappled with dimensionality in a different way, as will shortly become apparent.

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The first dimension higher than the one we are used to experiencing and take for granted is of course the fourth. As a concept the fourth dimension can trace its roots back to classical times, but was developed in the nineteenth century by mathematicians, some of whom were either amateur mathematicians or stumbled upon it in their research related to a number of other sciences. Aristotle discussed dimensionality in *De Caelo*,[1] and Ptolemy denied and disproved the existence of the dimensions higher than the third, but nevertheless contemplated it.[2] Many centuries later, the English mathematician John Wallis began to interrogate the possibility of the extension of three into further dimensions although he dismissed it at the outset:

> A line drawn into a line shall make a plane or surface; this drawn into a line, shall make a solid: But if this solid be drawn into a line, or this plane into a plane, what shall it make? A plano–plane? That is a monster in nature, and less possible than a Chimaera or Centaure. For length, breadth and thickness, take up the whole of space. Nor can our Fansie imagine how there should be a fourth local dimension beyond these three (Wallis 1685: 126).

During the French Revolution, the revolutionary mathematicians D'Alembert and Lagrange[3] were the first to accept the possibility that the fourth dimension can be considered to be time. Lagrange in particular spoke of three coordinates to describe the space of three dimensions, and introduced the fourth as the function of time (Lagrange 1797: 223). He then justified the introduction of the fourth dimension by denoting it $t$ and showing that it has already been considered in mechanics, hence making it acceptable to adopt such practice elsewhere.

Therefore, whilst people have grappled with the concept for a very long time and occasionally considered it in greater depth, only to regularly refuse to deal with it, finally in the nineteenth century the doors were re-opened to this area of geometrical investigations. Perhaps it was the invention of non-Euclidean geometries, or the projective geometry, or even the social upheavals of the preceding (revolutionary) era, or a mixture of all of these, but in any case the possibility of describing the fourth dimension mathematically, even if it is difficult to imagine it physically, began to resurface.

[1] 'A magnitude if divisible one way is a line, if two ways a surface, and if three a body. Beyond these there is no other magnitude, because the three dimensions are all that there are, and that which is divisible in three directions is divisible in all' (Aristotle 2012, 268a:10–15). But the possibility of an extension of dimensions appeared to Aristotle, although he rejected it little later: 'All magnitudes, then, which are divisible are also continuous. Whether we can also say that whatever is continuous is divisible does not yet, on our present grounds, appear. One thing, however, is clear. We cannot pass beyond body to a further kind, as we passed from length to surface, and from surface to body' (Aristotle 2012, 268a:25–30). For further reference on Aristotle's mention of the dimensionality in other works, see (Cajori 1926).

[2] Mentioned in Cajori (1926: 397), original description appearing in (Heiberg 1893: 7a, 33).

[3] Joseph-Louis Lagrange (1736–1813), a French-Italian mathematician, and his colleague Jean-Baptiste le Rond d'Alembert (1717–1783) mathematician, philosopher, co-editor of *Encyclopédie*, the first modern encyclopedia (by known contributors), published between 1751 and 1772.

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# Projecting an Architectural Perspective: Euclidean Propositions and Common Practices at Gonçalves Sena's Workshop

João Cabeleira[1] · João Pedro Xavier[2]

Published online: 17 June 2016


**Abstract** The projection of architectural perspectives, from the drawing plane to the tectonic support, might be the central problem of *quadratura*. However, specialized treatises tend to treat it through ideal statements. Highlighting the materialization of abstract reasoning, those demonstrations serve the scientific legitimation of *quadratura* practice, possibly circumscribed to enlightened scientific and artistic circles, rather than the dissemination of procedures aiming to train people in the projection craftsmanship. This may even be the best-kept secret of the *quadratura* painters. In this context, this paper is focused on Sena's *quadratura* (1754), at the church of Santarém's Jesuit College, where under Vieira's statements exposed in his treatise on perspective (*Tractado de Prospectiva*, Codex 5170, Biblioteca Nacional de Lisboa, 1716), we will disclose procedures based upon common practices of the painter's workshop concerning the outline and projection of the image.

**Keywords** Perspective · Optics · *Quadratura* painting · Projective geometry · Virtual architecture

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Birkhäuser

## Introduction

Considering the projection of architectural perspectives as the central problem of *quadratura* practice, this article aims to unveil practical procedures hidden under theoretical statements widespread through specialized treatises. As such, the scope of *quadratura* conical projection is taken as practical procedures that allow for the outlining of linear structures onto curved surfaces. Although the theoretical framework is based upon ideal schemes and narratives of scientific demonstration, the common practice at the painter's workshop is assumed here, along with the material circumstances of the *quadratura* projection. The recent essays by Hoffmann (2009) and Camerota (2010) have looked at the problem without the constraints imposed by idealized procedures (such as Pozzo's *Modo di far la graticola nelle volte* or Danti's narrative of the *fili tesi* process), advancing into practical hypotheses. On the other hand, and concerning the primary sources reported here, studies on Inácio Vieira's treatise (1716) do not fully analyze the *quadratura* projection resolution, despite their value in rescuing the document, identifying its sources and organizing its main contents (Leitão and Mello 2005; Mello 2002; Raggi 2004; Trindade 2015). In the same order, Gonçalves Sena's *quadratura* (1754) was brought into daylight by recent art history studies on Portuguese *quadratura* (Mello 2001, 2002; Raggi 2004) although they call for further developments of its projective and architectural features.

In this sense, and under the recent considerations on both objects (Cabeleira 2015), a thorough review of Vieira's manuscript and Sena's *quadratura* identifies procedures for creating the image outline and its projection. Their cross-referencing leads to theoretical hypotheses tested upon graphical models that allow us to ascertain its validity as well as to communicate and visualize the aroused assumptions.

Based upon Euclidean propositions, the theoretical enunciation by Vieira coincides with the empirical reasoning undertaken at Sena's workshop, a consideration that allows us to detach the method from ideal schemes and advance towards a practical solution. Delimiting the exposed reasoning to this issue, unveiling the best-kept secret by *quadratura* painters, we aim to clarify the *quadratura* projection practice through a simplified process that sends us back to the very fundamentals of geometric knowledge, the Euclidean propositions.

## Approaching the Problem Through Sena's *Quadratura*

The study of Inácio Vieira's manuscript on perspective (1716) and the perspective restitution of Gonçalves Sena's painted architectural perspective (1754) at Santarém's Jesuit College (Fig. 1), demonstrates that alternative models of *quadratura* projection may be considered.[1] Although both authors assimilate

[1] Gonçalves Sena (1713/1790) was a self-taught spirit whose apprenticeship and artistic update arises from the study of coeval treatises (Benedicto 1791: 8), necessary to the scientific and iconographic codification of the pictorial practice. He started as an easel painter, developing, progressively, capacities as a mural painter and finally as a quadraturist.

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# Singularities of Perspective in Spain: The 'Other Treatises' on Perspective and their Importance within the European Context

**José María Gentil Baldrich[1] · Andrés Martín-Pastor[2]**

Published online: 28 July 2016


**Abstract** Regarding drawing perspective, Spanish tradition has hidden singularities that greatly distinguish it from other European traditions. Spanish tradition, however, simultaneously nurtures ideas from these traditions, such as those of Italy and France, creating multiple variations and novelties. This study presents a brief journey through the lesser-known exempla, which are lesser studied in the scientific community. The study focuses on the 'angular perspective' by architect Hernán Ruiz the Younger (el Joven), the innovative construction of figures in perspective by the carpenter Antonio de Torreblanca and the singular contributions to the anonymous manuscript *Artes Exçelençias dela Perspectiba*. All three studies are similar in that they feature novel and heterodox premises within the general theory.

**Keywords** Historical treatise · Manuals · Perspective · Geometric construction · Representation of architecture · Polyhedra

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## Introduction: Perspective Manuscripts in the Spanish Tradition

As it is commonly known, the study of perspective is a multidisciplinary approach comprising a number of individual yet interrelated areas of knowledge. Despite essentially being an issue of language and communication, its expression is also a question of ideology. The study of perspective is also, in its purest form, an instrumental issue; it is both geometric and technical which enables its use and application (Gentil Baldrich 2012b).

Accordingly, we cannot speak of a single tradition on perspective in Spain since it has evolved over the centuries. Its grammar has been constructed from different axioms and even fashions. Thus we shall speak of a unique 'angular perspective' in Spain, inspired by the scientific teachings of Euclid and crossed with an Italianized vision of perspective that eventually dominated artistic circles and guilds. This was made possible by direct contact with Italian and Flemish artists in the cultural melting pot that was the works of Phillip II's Escorial palace in Madrid. Also key was the arrival of prestigious treatises, full of innovative and impressive illustrations, such as those of Vignola and Danti (1583) and Sirigatti (1596).

The eventual use of perspective construction based on the intersection of the visual pyramid with the picture plane rather than more abstract methods must also be analyzed within an evolutionary logic. It is the result of the advantages of this particular method in saving time and effort over more confusing and complex methods. The methodological evolutions that followed, from the 'seconda regola' by Vignola and Danti, the 'punctus contingentia' by Marolois (1633), or the perspectograph, up to the *camera obscura* and finally the photograph, also seek 'the easiest way', as previously expressed by Albrecht Dürer.

However, we should bear in mind that, besides painters, representing space on a plane is also an issue for architects, carpenters and engineers (Burucúa 1989-1990-1991). Any builder in a complex production system going beyond medieval guild logic needs a method to define and control objects in space starting from a projection plane. In accordance with this they must measure and define all the geometric parts, create templates, calculate expenses, and finally visualize the work before its construction. In this way the evolution reflected in the perspective treatises reveal the true manuals of graphic science in each historical period including the geometric corpus, and theory of polyhedral and projection issues. These form the basis from which all modern systems of representation have been defined, from Monge (1797) to the arrival of CAD technology.

In Spain there are key examples of this trend, outside of pictorial tradition, which deal with the graphical problems within construction crafts. These manuscripts had a private and professional use but in other cases were conceived as real treatises, even prepared for editing but then never published. Within this group of manuscripts the following have been studied: Ruiz (1560),[1] Antonio de Torreblanca

[1] The manuscript was studied and edited by Navascués Palacio (1974), then by Alfonso Jiménez Martín (AA.VV. 1998). Regarding the section on perspective, previous research was done by Cabezas-Gelabert (1984), Gentil Baldrich (1998), and Gentil Baldrich (2012b: 97–107).

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# Reciprocal Frames in Temporary Structures: An Aesthetical and Parametric Investigation

**Francesco Gherardini[1] · Francesco Leali[1]**

Published online: 14 August 2017


**Abstract** This paper deals with the use of reciprocal frames in temporary gridshell structures, such as architectural pavilions in expositions and installations. These architectural examples can benefit from the use of short, easy to handle, generally joint-free, and repeatable "modules" in order to create particular self-supporting structures. The lightweight and interwoven grid obtained by connecting short elements according to the reciprocity principle is structurally efficient and, at the same time, aesthetically pleasing, mainly due to the resulting tessellation. The paper firstly investigates the connection between efficiency and aesthetics. The last part of the paper investigates some temporary architectural pavilions from both an aesthetical and parametric point of view. In order to deepen our understanding of these structures, they are re-modelled according to a bottom-up approach by means of a constraint-based parametric CAD modeller. In this way, a reciprocal frame can be explored and modified by the parametric arrangement of its generative elements, which, like a natural organism, grows in self-generating forms.

**Keywords** Reciprocal Frame · Shell structure · Parametric modelling · Architectural pavilions · Tessellation · Aesthetics · Natural form

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Birkhäuser

## Introduction

A reciprocal frame (RF) is a three-dimensional grillage structure based on elements (beams, elongated elements or laminae) that mutually support each other. The origins and general characteristics of RFs have been examined in depth previously in this journal (Di Carlo 2008; Duvernoy 2008; Baverel and Pugnale 2014; Pugnale and Sassone 2014; Thönnissen 2014) and will not be gone into here.

Popovic Larsen (2007) defines the multiple RF grids as "reminiscent of gridshells", because of some specific characteristics. A gridshell is a structure defined by a curved (3D) surface (called "shell") and made of a grid instead of a solid surface (Douthe et al. 2006). The grid members can be continuous (spanning across the whole structure and overlapping each other at the nodes) or discrete (short beams (or rods) connecting to each other at nodes) (Naicu et al. 2014).

In order to better contextualise RFs among discrete grid member structures, and according to many authors, the hallmarks of a RF structure are:

1. it is formed by expanding and adding single RF units to the perimeter of the single unit to form a grid structure (Popovic Larsen 2007);
2. each element must work, simultaneously, both as support and supporter of other ones, without any clear structural hierarchy (Pugnale et al. 2011);
3. its elements support one another along their span and never at the extremities (Baverel and Pugnale 2014);
4. the length of each element is shorter than the distance to be spanned by the whole structure (Pugnale et al. 2011);
5. its elements are generally joined using friction, notching, nailing or tying (Song et al. 2013); sometimes, in larger structures, mechanical joints such as scaffolding swivel clamps are used (Sénéchal et al. 2011).

The inherent nature of RFs make them suitable for temporary architecture, such as pavilions in exhibitions and expositions. On one hand, their construction principles lead to their main advantages in manufacturing, handling, shipping, assembly and disassembly, due to the use of short—and generally lightweight—elements. On the other hand, the geometric patterns originated by RF unit arrangements, which resemble natural structures, lead to impressive forms.

Although RFs present some specific features, most of the considerations proposed here concerning aesthetics, natural form, tessellation, and temporary use can be further extended to other short beam grids, as in the case of space grids with elements connecting at their ends by means of pin joints, fasteners or fixings.

To consider all of these aims, the paper is structured as follows. In the first section, "Behind Reciprocal Frames: Structure and Aesthetics", we investigate the relationship between structural geometric forms and aesthetics. In the second section, "Analysis of Reciprocal Frames", we propose a bottom-up modelling approach for developing a "design exploration" of four small pavilions, chosen as case studies for their specific features. These structures will be partially re-modelled according to the proposed approach in order to parametrically investigate their "growth", similar to a natural organism. A brief discussion concludes the paper.

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# The Lightfall and the Symbolic Function of the Hyperbolic Paraboloid Surface

**Eran Neuman**[1]

Published online: 13 October 2016


**Abstract** The paper discusses the symbolic function of the hyperbolic paraboloid surface in Preston Scott Cohen's design of the Lightfall at Tel Aviv Museum of Art and its precedents. While analysing several examples of the use of the hyperbolic paraboloid surface in architecture, the paper proposes three modes of symbolic use of the surface: operative, demonstrative and figurative.

## Introduction

In 2011, the Tel Aviv Museum of Art opened its new wing, the Herta and Paul Amir Building (Fig. 1). Designed by the American architect Preston Scott Cohen, the building is constituted of an external angulated envelope, an internal centerpiece that Cohen named the Lightfall, and galleries that link between the external surface and the internal centerpiece. Although equally important and exquisite in their forms, the Lightfall drew more attention than the external envelope. This might be because Cohen highlighted the complexity of the centerpiece as an organizational atrium. It might be also due to the ways in which the shape was conceived and executed. Rising to a height of 26.5 meters, the Lightfall is composed of hyperbolic paraboloid surfaces positioned in various angles in relation to one another.

In the following paper, I would like to discuss my claim that the significance of the Lightfall goes beyond its shape and form and beyond its mathematical idea. Over the years, the hyperbolic paraboloid surface has been implemented in many ways. Each implementation carried significance beyond the structural and mathematical realm. The Lightfall is not different in that respect. In this essay, I

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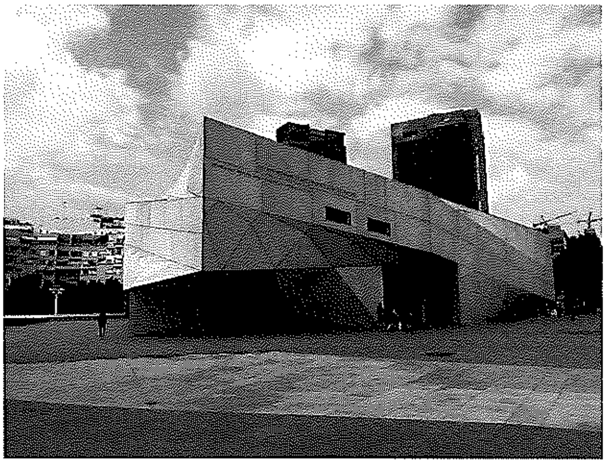

**Fig. 1** Tel Aviv Museum of Art, the Herta and Paul Amir Building. Architect: Preston Scott Cohen

would like to propose a discussion of three different ways in which the surface is used as a symbol; each way stems from a different cultural condition and each represents a different meaning. Together, they constitute a comprehensive understanding of symbolic use of the mathematical shape.

I will start with a discussion of Cohen's Lightfall as an operative symbol. Then, by referring to two other prominent examples of the use of the hyperbolic paraboloid surface—first, to Vladimir Grigoryevich Shukhov's groundbreaking installation of the hyperbolic paraboloid surface in a tower at the All-Russia Industrial and Art Exhibition in Nizhny Novgorod in 1896, and second, to Le Corbusier and Iannis Xenakis' use of hyperbolic paraboloid surfaces in the Assembly Hall in Chandigarh and in the Philips Pavilion at Expo 58 in Brussels—I will expand on the symbolic role of hyperbolic paraboloid surfaces in architecture.

## The Lightfall and the Operative Symbolism of the Hyperbolic Paraboloid Surface

Cohen, a professor of architecture at Harvard University's Graduate School of Design and a former chair of its Masters in Design program, evolved out of the academic sphere. His architectural ideas, mostly about contested geometries, were developed in these circumstances (Cohen 2001). It is not surprising, then, that Cohen often related his work to precedents in architectural history. Thus, he often compares the Herta and Paul Amir Building to Los Laboratorios, a building designed by the Spanish architect Miguel Fisac that was inaugurated in Madrid in 1968 (Cohen 2011). Fisac, who was a master of modern architecture and one of Spain's leading architects in the second half of the twentieth century, planned the building as an office and storage facility for the medical company Jorba. Cohen refers to this building and compares it to the new wing of the Tel Aviv Museum of Art because both he and Fisac used hyperbolic paraboloid surfaces, or hypars, in their buildings.