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KWB KIM WILLIAMS BOOKS NEXUS 2025 - Relationship Between Architecture and Mathematics - Conference Book

# VICENZA NEXUS

Relationship Between  
Architecture and  
Mathematics

Conference Book



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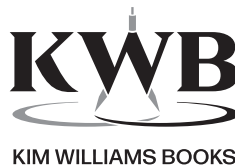


*Nexus 2025:  
Relationship Between Architecture and Mathematics  
Conference Book*

Civil, Environmental, and Architectural Engineering  
Department  
University of Padua  
and  
Kim Williams Books  
*present*

Nexus 2025  
Relationship Between  
Architecture and Mathematics  
Conference Book

edited by  
Kim Williams and Cosimo Monteleone



**Nexus 2025: Relationships Between Architecture and Mathematics**  
3 – 6 June 2025, Palladio Museum, Vicenza, Italy

Organised by:  
Civil, Environmental, and  
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## PREFACE

*Kim Williams*<sup>1</sup>

We have the great privilege of presenting the Conference Book for Nexus 2025: Relationships between Architecture and Mathematics, held in a very special city: Vicenza, home to Andrea Palladio. This year's meeting is hosted by the Department of Civil, Environmental, and Architectural Engineering (Ingegneria Civile Edile e Ambientale, ICEA) of the University of Padova, and the conference days from 3 to 6 June continue the tradition of innovative, interdisciplinary research that began with the first Nexus conference almost three decades ago.

The conference series entitled "Nexus: Relationships between Architecture and Mathematics" began with a first conference in Fucecchio (in the province of Florence, Italy) held in June 1996. That first meeting has been followed by successive conferences held every two years: 1998 in Mantua, Italy; 2000 in Ferrara, Italy; 2002 in Óbidos, Portugal; 2004 in Mexico City, Mexico; 2006 in Genoa, Italy; 2008 in San Diego, USA; 2010 in Porto, Portugal; 2012 in Milan, Italy; 2014 in Ankara, Turkey; 2016 in San Sebastián–Donostia, Spain; 2018 in Pisa, Italy; 2021 in Kaiserslautern, Germany (but held online due to the COVID pandemic of 2020); 2023 in Torino, Italy. This year's fourteenth edition in Vicenza is a kind of dream come true for Nexus. We have never held a conference here, but following the second Nexus conference in 1998 a three-day post-conference workshop on the architecture of the great Vicentine architect was based in here.

This present volume is intended as both a guide to and a record of the Nexus 2025 conference. The division into sections and order of the papers reflects the program of the conference. The speakers were chosen on the basis of peer reviews of the proposals received after a Call for Presentation Proposals published in September 2024. Conference director Cosimo Monteleone and Conference Secretary Sylvie Duvernoy were responsible for receiving and sorting the abstracts for peer review. The Scientific Committee, whose members are listed in the front of this volume, were responsible for evaluating all of the abstracts by replying to the following questions:

- Is the subject matter on-topic for the Nexus 2025?
- Is the topic original, or is it well-known?
- Will the topic be interesting for most conference participants or is it highly specialized and of interest to only a few?
- Does the research appear to be well developed?
- Does the research include results on the same topic already discussed at previous Nexus meetings?

The reviewers were also given the possibility of adding comments that they believed might help improve the abstract in view of a presentation at the conference. The 56 abstracts included here were selected among all those received because they received excellent scores during the evaluation process.

For presentation during the conference, the selected abstracts were grouped as nearly as possible into sessions by topic: "architectural analysis" (2 sessions); "mathematics behind the design"; "algorithmic design"; "rule-based design"; "didactics"; "perspective and projection"; "surveys and models"; "urban design"; "structures"; "geometric design";

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<sup>1</sup> Kim Williams, Director, Nexus: Relationships Between Architecture and Mathematics Editor-in-Chief Emerita, *Nexus Network Journal*

“reconstruction and modelling”. This list alone provides an idea of the breadth of field of studies in architecture and mathematics.

The conference concludes with a session devoted to the research carried out by students who are currently enrolled in Ph.D. programs, and Ph.D. degree holders who have earned their degree in the past 2 academic years (2023-2025). This part of the conference, a session for PhD research that was first introduced at Nexus 2012 in Milan, aims at providing students with the possibility to present their research to a group of professional scholars and architects and receive feedback that will allow them to refine their ideas.

The Nexus 2025 conference comprises three days of plenary presentations in both morning and afternoon sessions. All speakers are allotted 20 minutes for their presentation with 5 minutes for questions at the end, and answers. Coffee breaks and shared lunches also provide further opportunities for discussions and exchanges. It was the combination of formal presentations and informal discussions that have often led to new lines of research and collaboration.

As many Nexus participants already know, I personally founded the Nexus conference series in 1996, and was the director of all things Nexus through 2023. In 2024 the scientific journal Nexus Network Journal, which was founded to accompany the conferences, was acquired by SpringerNature, and continues to be published by them, while I retired. This year’s conference was organized by the newly-founded “Nexus Architecture and Mathematics APS”, the non-profit association founded expressly to coordinate Nexus conferences. The association, and the commitment of the association’s officers will assure unbroken continuity of the conferences in the years to come. I particularly thank the association’s president, Sylvie Duvernoy; the secretary Maria Zack; the treasurer Marco Giorgio Bevilacqua; and the vice treasurer Roberta Spallone, all of whom worked feverishly to cut through the red tape and establish the association in time for this year’s conference. We are very grateful indeed to the Palladio Museum and to the Centro Internazionale di Studi di Architettura Andrea Palladio and its director, Guido Beltramini, for supporting Nexus.

Many, many thanks to the Scientific Committee for contributing their time and expertise to the selection of the abstracts.

I would also like to thank pianists Stefania Redaelli and Maria Grazia Bellocchio for offering us the chance to hear a piano concert for four hands featuring the Hungarian Dances of Johannes Brahms, in the splendid context of Vicenza’s Teatro Olimpico.

Naturally, we would not have a conference without our presenters. Thanks to all the authors present in this book, for considering Nexus as the venue for the presentation of their research, and for devoting time and money to be here in person for the conference.

Finally, I would also like to wholeheartedly thank this year’s co-director, Cosimo Monteleone of the ICEA. He is to be thanked especially for contacting the Palladio Museum and obtaining permission for us to hold our conference in their splendid headquarters. He was also in charge of the page layout of the abstracts in the book you are now holding in your hands (or reading on your laptop).

Kim Williams

Cremona, June 2025

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Tuesday, 3 June 2025  
Architectural Analysis 1 and 2  
Mathematics Behind the Design

# GRAPH APPLICATIONS AND ORIENTATION FOR EXHIBITION SPACES

*Cristina C ndito,<sup>1</sup> Maria F. Pacheco<sup>2</sup>*

## **Introduction**

The research investigates the application of some mathematical tools for the analysis and design of architectural paths and spaces. The aim is not to attribute the phenomenon of architectural space configuration to automatic mechanisms but rather to verify the effectiveness of systematic analysis to establish relationships between paths and built environments, particularly in the context of exhibition spaces. For this purpose, the concept of the graph is introduced, in its historical context linked to the formulation of cyclical paths without repetition, and in its dimension developed in the Space Syntax studies to indicate spatial connections. A qualitative approach has also been explored with regards to the characteristics influencing orientation linked to simplifying the distributive graphs of the environments, which can also lead to the evaluation of alternative spatial geometries.

## **The Research**

### *Architectural Questions and Themes*

This study seeks to answer the following two questions:

1. Is it possible to obtain quantitative data to verify and conceive the functionality of a path within an architecture?
2. What are the elements based on wayfinding theories that can help users understand an exhibition path?

For the analysis of the connective characteristics between spaces, the typology of exhibition areas was chosen as a case study, hypothesizing an experiment aimed both at the configuration of schematic spaces, which allows a designer to highlight the individual characteristics of the distribution choices, and an architectural example, which demonstrates the interaction with other spatial peculiarities.

Considering the centrality of the theme of connections, the research examines the topological field in order to abstract from the metric characteristics. In particular, the graph method, conceived by the mathematician Leonhard Euler in 1735 (Alexanderson 2006), was considered, for its ability to provide a circuit path without repetition and provide quantitative data, such as the *depth index*, as shown by contemporary studies in the context of the Space Syntax theory (Dawes, Ostwald 2013; Cochez 2021). A deeper understanding of certain mathematical principles is crucial to fully understanding the applications of this tool and how it can be applied to the challenges of wayfinding.

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*Mathematical Concepts and Answers*

A graph is a mathematical structure consisting of a set of vertices (or nodes) and edges representing the connections between the vertices. In this section, several concepts and structures that characterize graphs will be introduced and applied in order to show how different spatial configurations can impact circulation and overall user experience in an exhibition space.

In a given graph, vertices adjacent to each other are called *neighbors*. The number of edges that are incident in a vertex  $x$  is called the *degree of  $x$* . A *regular graph* has all vertices with the same degree. In the context of architecture, it represents a space where all nodes (assumed to be rooms) have an equal number of connections to adjacent spaces. This uniformity can help in evaluating spaces designed for equitable distribution of movement.

A vertex with an even number of neighbors is an *even vertex*, and a vertex with an odd number of neighbors is an *odd vertex*.

The graph in Figure 1 is not regular because it has vertices with different degrees. Vertex 2 (as vertex 5) has degree 3, so it is odd. Its neighbors are 1, 3 and 5. Vertices 1, 3, 4 and 6 have degree 2, so they are even vertices.

In graph theory, *paths*, *walks*, and *trails* are different ways to explore and connect the elements of a graph. Each concept represents a journey through the vertices and edges of the graph, with its own set of rules. While a *path* is a sequence where vertices and edges may be repeated (Fig. 1 a), a *walk* is a sequence with no repeated edges (Fig. 1 b), but where vertices may repeat. A *trail* is a sequence of vertices with no repeated vertices or edges (Fig. 1 c), and it can correspond to a sequence of rooms or spaces where each connection is unique, and no room is revisited. This can be used to model efficient evacuation routes or visiting tours.

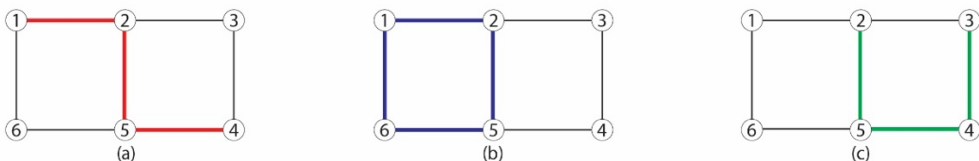


Fig. 1. A non-regular graph with different pathways. (a) Path (1-2-5-4-5), (b) Walk (1-2-5-6-1), (c) Trail (3-4-5-2).

The next concepts, *circuit* and *cycle*, are used to model pathways that return to their starting point and, therefore, with connections that form closed loops. The way these loops are defined - whether by allowing or restricting repeated vertices or edges - gives rise to the two distinct concepts: a *circuit* is a closed walk where the start and end vertices are the same and a *cycle* is a closed trail with no repeated vertices except the start and end vertices. *Circuits* and *cycles* are important concepts in the design of loops in exhibition spaces that ensure visitors are guided back to the entrance.

An Eulerian circuit in a graph is a closed path that visits every edge exactly once, though it may revisit vertices. A graph is called Eulerian if it has such a circuit. On the other hand, a Hamiltonian cycle is a closed path that visits every vertex exactly once, without repeating vertices or edges. A graph is called Hamiltonian if it has a Hamiltonian cycle.

Eulerian circuits focus on covering all edges exactly once, while Hamiltonian cycles focus on visiting all vertices exactly once. The distinction between Eulerian and Hamiltonian graphs provides insights into designing efficient navigation systems. A Eulerian graph could be applied to the design of routes that minimize retracing steps, such as optimized cleaning or maintenance pathways in a large exhibition hall. For a Eulerian graph to exist, all nodes must be even. On the other hand, a Hamiltonian graph focuses on cycles that visit each space exactly once.

These seven concepts are particularly relevant in wayfinding within exhibition spaces, where a visitor might want to experience every room without repetition, forming a coherent and logical exploration path. On the other hand, determining whether a graph is Hamiltonian and finding a Hamiltonian cycle (if it exists) is an extremely difficult problem since as the size of the graph increases, the number of possible ways to visit the vertices grows exponentially. This makes it hard to check all possibilities efficiently, especially for large graphs (Harary 1969).

#### *Case study: an Exhibition path*

To experiment with the multiple applications of the concepts and tools of graph theory and to integrate them with the themes of wayfinding, we brought a simple rectangular plan, divided into six squared subspaces, a succession of different rooms connected through an exhibition path.

Among all the possibilities, we chose to illustrate two variants: the one with the access at the center of the short side of the rectangle (Fig. 2, column A) and the one with the entrance at the center of the long side (column B). We applied the method of the graph thinking of a succession of spaces according to the simplest one: a perimeter path (A1 and B1). Then we considered involving the movement that alternated between the sides of the perimeter (A2, B2.1 and B2.2), without detecting significant differences between the two initial categories in the path definition.

We examined the situation without odd nodes (B2.1), defined as a Eulerian graph, which guarantees the existence of a circuit that returns to the starting point. Then we considered the variant with two odd nodes (B2.2), called semi-Eulerian, which allows for an exit different from the entrance. In any case, it is a matter of not retracing the same edge, an important aspect of exhibitions layouts.

In all of these cases, we can observe that the succession of these spaces creates a progressive increment of the *depth index* (Hillier, Hanson 1984, p. 108) which indicates, with a numerical progression, the degree of connection between two spaces.

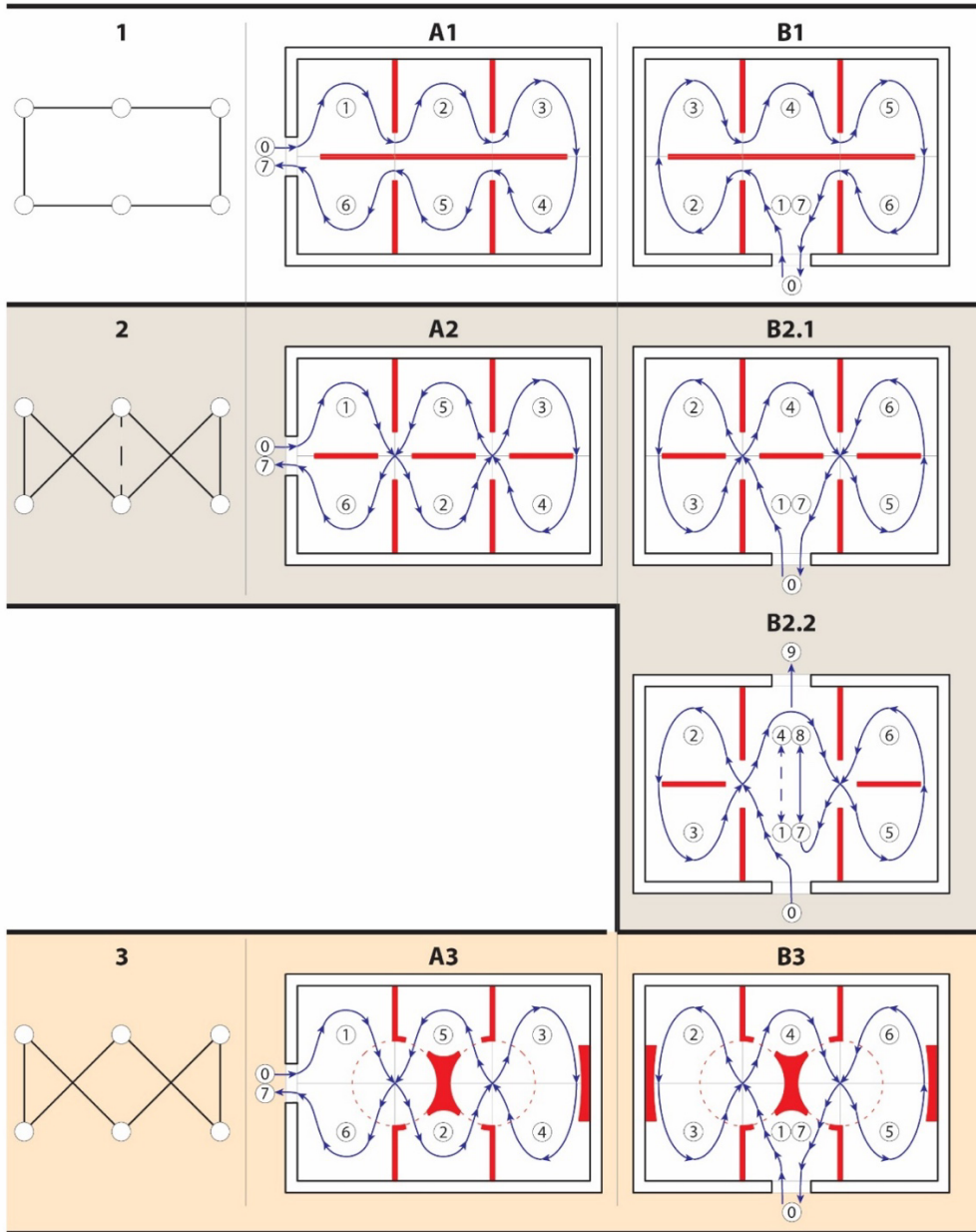


Fig. 2. Variations in paths in the same spaces.

In version 3, shaped panels and floor lines have been introduced to provide useful guides for finding the correct exhibition route. These are just some of the many elements that can affect the effectiveness of wayfinding and are linked to the geometry of the spatial margins. One can also consider elements linked to the possibility of recognizing the starting point, perhaps through an overall perspective view. The turns also have a great influence in

wayfinding: they should be limited in number as well as regular in angle (Dalton Conroy et al., 2015).

The graphs in cases 1, 2, and 3 are Eulerian and Hamiltonian. This dual nature means that they can accommodate both edge-centric and vertex-centric navigation strategies, ensuring that the way visitors move through the space is comprehensive and efficient. These graphs are *isomorphic* in the sense described by Hillier (Hillier 2007, p. 88), meaning they represent the same abstract mathematical object regardless of the specific spatial configurations they correspond to.

A further possibility is offered by a central distribution space with the aim of creating a fulcrum of radial directions, or star graph, that allows for a return to the starting point, without considering Eulerian or Hamiltonian principles. This is an important feature in wayfinding and every space has a *depth index* = 1. This arrangement recurs in exhibition architecture and can be found in the emblematic example of the Genoese Museo del Tesoro, realized by Franco Albini (1956; Dezzi Bardeschi 2015).

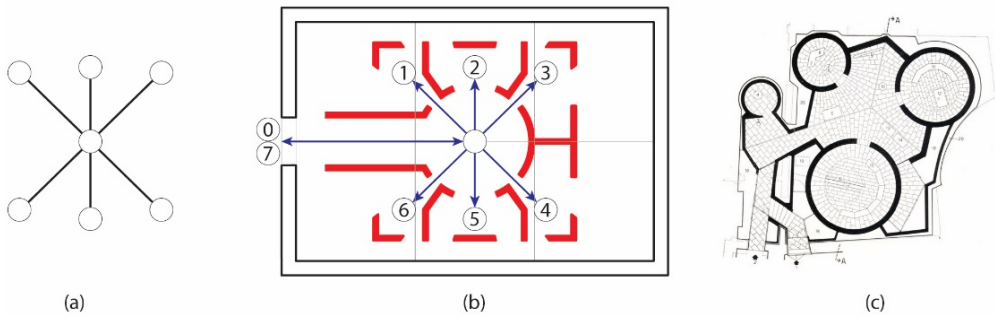


Fig. 3. The star graph (a), its modulation inside the previous spaces (b), and the example of the Museo del Tesoro (Franco Albini, Genoa, Italy, 1956).

The tools provided by graph theory - those that identify Eulerian circuits and Hamiltonian cycles, among many others - are especially helpful when dealing with more complex or larger spaces since they offer systematic and well-defined methods to guide practical decisions for planning and navigating such spaces. If we consider a more articulated space, a designer can choose, for example, the entrance and the exit in a disposition of space by attributing them odd nodes (Fig. 4 a) and then letting the other nodes assume an even value (Fig. 4 b) to obtain a circuit without repetition.

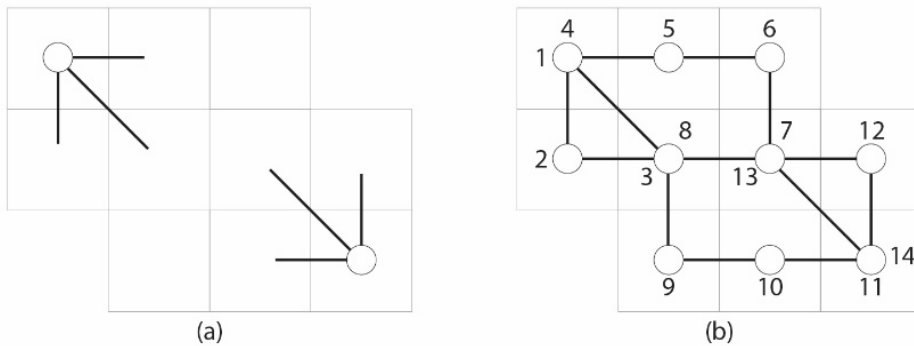


Fig. 4. The graph and the circuit as a design tool.

## Conclusion

The primary aim of this research is to experiment with the mathematical tool of graphs in analysing and designing architectural spaces. The consideration of the Eulerian and Hamiltonian circuits and cycles or the depth index cannot define an architectural space, but it can help to understand or attribute some features in exhibition architecture, without forgetting its three-dimensional qualities and their impact on the users' orientation and understanding of the space.

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## References

- Alexanderson, G. L. 2006. About the cover: Euler and Königsberg’s Bridges: A historical view. *Bulletin (New Series) of the American Mathematical Society*, 43(4), 567–574. <https://doi.org/10.1090/S0273-0979-06-01130-X>
- Cochez, M., et al. 2021. *Graph Structures for Knowledge Representation and Reasoning: 6th International Workshop, GKR 2020*, Virtual Event, September 5, 2020, Revised Selected Papers. Cham: Springer Nature.
- Dalton Conroy, R., Hölscher, C., Spiers H. J. 2015. Navigating Complex Buildings: Cognition, Neuroscience and Architectural Design. *Studying Visual and Spatial Reasoning for Design Creativity*, pp. 3-22. Netherlands: Springer. [https://doi.org/10.1007/978-94-017-9297-4\\_1](https://doi.org/10.1007/978-94-017-9297-4_1)

- Dawes, M., Ostwald, M.J. 2013, Precise Locations in Space: An Alternative Approach to Space Syntax Analysis Using Intersection Points. *Architecture Research*, 3(1): 1-11.
- Dezzi Bardeschi, M. 2015. *Conservare il moderno: Franco Albini e il Museo del Tesoro di San Lorenzo a Genova*. Firenze: Altralinea.
- Harary, F. 1969. *Graph Theory*. New York: Addison-Wesley Publishing Company.
- Hillier, B., Hanson J. 1984, *The Social Logic of Space*. Cambridge: Cambridge University Press.
- Hillier, B. 2007. *Space Is the Machine: A Configurational Theory of Architecture*. London: Space Syntax, <https://discovery.ucl.ac.uk/id/eprint/3881>. [first ed. *Space is the Machine: A Configurational Theory of Architecture*, Cambridge 1996].