PORTO

3 - 6 DECEMBER 2024

Formal Methods in Architecture

7th International Symposium - Book of Abstracts

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Title
Formal Methods in Architecture:
7th International Symposium
Book of Abstracts

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FORMAL METHODS IN ARCHITECTURE
7TH INTERNATIONAL SYMPOSIUM

The 7th Symposium on Formal Methods in Architecture (7FMA) aims to contribute to the discussion in architecture and urbanism on the application of new formal methods to emerging social and technical issues. The focus will be on methodological advances based on recent developments in collaboration with mathematics and computer science, applied to architecture and urbanism at different levels of abstraction and formalization.

2024's FMA will focus on the connection between formal methods and architectural practice. With the proliferation of digital technologies, which every day allow increasingly intelligent tasks to be delegated to automated tools and have immense potential to increase productivity, it is urgent to examine the gap that often exists between scientific endeavors and practical applications in everyday architectural work.

Each Symposium edition has showcased complex methods and exciting advancements in the various fields under the FMA umbrella: we have witnessed how artificial intelligence, generative grammar, and other forms of design automation can be implemented into the design process; we have also explored how spatial analysis methodologies can provide a systematic understanding of large-scale social processes and can be applied to comprehend the social outcomes of architectural interventions; we have observed GIS, photogrammetry, and other methods for collecting and organizing data become simultaneously more sophisticated and user-friendly every year and see how virtual and we have seen how virtual and augmented reality not only

facilitate visualization but also enhance our understanding of designs and can be incorporated into interactive design environments; we have examined how this myriad of formal methods be used for the development of smart buildings and cities and to facilitate participatory processes. Simultaneously, and in parallel, we have witnessed the growing pressure put by the construction industry on architecture offices to implement CAD and BIM technology. It is in this context that, with this edition of the Symposium, we wish to discuss, disseminate, and promote the use of formal methods in the creation of new explicit languages for the solution of architectural and urban problems.

Recognizing that architecture and urbanism requires both technological and artistic approaches, the 7th Symposium will address current challenges in these fields, including production, sustainability, design, representation, communication, and heritage. The potential and limitations of using formal methods to address these challenges will also be explored. Researchers, professionals, and students in the fields of architecture, urbanism, landscape design, civil engineering, and computer science are invited to attend. The event will cover the following topics:

- **Collection of information**: including tracking and mapping methods (video, GPS, WiFi, ISP, IoT, cellular phones); biometric sensing; surveying; photogrammetry and 3d scanning through drones, photography, or laser; machine learning; computer vision.
- **Semantic organisation of information**: including Geographic Information Systems – GIS; Building Information Models – BIM; Industry Foundation Classes – IFC; Ontologies for the built environment.
- **Formal theories and methodologies of spatial analysis**: including Space Syntax; visibility graph analysis; Space Configuration, Accessibility and Visibility Analysis (SCAVA); agent-based analysis; rule checkers.

- **Representation, visualisation and interaction: including CAD; renderings and animated motion**; mixed realities (virtual, augmented); human-computer interaction.
- **Authomation of architectural design**: including parametricism; generative design; shape grammars; processing; advanced reasoning artificial intelligence tools.
- **Active management of the built environment**: including participatory architecture and urbanism; smart buildings and cities; life cycle management; 6-7d BIM; facilities management; flow and crowd management.
- **Computer aided production**: including CAM, Scale models, 3-4-5D BIM and automated manufacturing.
- **Formal Methods in teaching architecture:** including teaching methodologies; learning experiences and digital training; spatial reasoning through visual programming and coding.

The Symposium encourages submissions that enhance and advance these and related themes using novel or established methodologies, case studies, theoretical and historical perspectives, analytical experiments, and other methods. It seeks contributions from a diverse range of fields, including proposals that explore non-traditional formats (e.g., artistic, performative, demonstrative, etc.). In proposing a topic as broad as formal methods in architecture, we aim to facilitate the exchange and generation of knowledge through interdisciplinary communication.

PROGRAMME

3-6 DECEMBER 2024

Day 1 - December 3

09:00 - 13:00 WORKSHOPS

"Reabilitação 4.0": a fase de caracterização prévia na era da transição digital

14:00 - 18:00 WORKSHOPS

Motion Mapping: Introductory Workshop on Architecture & Urban Simulation with AnyLogic application

Transforming Existing Buildings: A Collaborative Scan2BIM Workflow for Enhanced Design

09:00 - 18:00 WORKSHOPS

Immersive Architectural Perception: Real-Time VR and 3D Modeling Workflow

Building the Future – Robotic Construction Simulation with VR/AR

Understanding Algorithmic Design: learning algorithms through illustrations

Biomimicry Meets Computation: Generative Design and AI for Human-Nature Symbiosis

Introductory Course on GIS in Architecture and Urban Planning Practice (QGIS)

Day 2 - December 4

09:00 - 09:30 WELCOME & REGISTRATION

09:30 - 10:00 OPENING SESSION

10:00 - 11:30 PAPER SESSION 1

Plot systems and adaptation: a method for analysing space and time – *Lais Bertolino, Vitor Oliveira*

Deciphering urban morphogenesis: A morphospace perspective – *Caio Cacholas, Dries Daems, Fabiano Lemes Ribeiro, Howard Davis, Vinicius de Moraes Netto*

Co-learning between research and practice in planning: adressing the physical form of cities – *Ana Mélice Dias, Vitor Oliveira*

Can topography favour the competitiveness of pedestrian over car? – *Nuno Gomes, Vitor Oliveira, Álvaro Costa, Miguel Lopes*

11:30 - 12:00 COFFEE BREAK

12:00 - 13:30 PAPER SESSION 2

Visualizing urban experience: AI and computer vision framework for historic commercial streets in Egypt – *Nabil Mohareb*

Space Syntax as an agent based system. NEtlogo framework proposal – *Ana Cocho Bermejo, Dave de Jonge*

Analyzing the network nffects of vertically layered urban structures on pedestrian movement: A case study of the Mostar Interchange in Belgrade – *Aleksandra Djukic, Nikola Mitrovic*

13:30 - 14:30 LUNCH

14:30 - 15:30 KEYNOTE SESSION 1

José Pinto Duarte

Additive Construction on Earth and beyond: from research to practical applications

15:30 - 17:00 PAPER SESSION 3

The effect of potential urban elements on finding direction in urban space exampling of Kadiköy- Yeldegirmeni – *Buse Erkan, Mehmet Emin Salgamcioglu*

Formalization and education in architectural and urban design: their hermeneutic dimensions – *Carmen Escoda, Josep Muntanola, Magda Saura, Margaret Krawecka, Regina Garcia*

Reimagining human-nature coexistence: an integrative approach to architectural design with Biomimicry, Generative Modeling, and AI – *Carina Oliveira, Mauro Costa Couceiro*

Reimagining digitalized space: Integrating meaning and technology in building Systems – *Kaiko Kivi*

17:00 - 17:30 COFFEE BREAK

17:30 - 18:30 PAPER SESSION 4

Architecting the Metaverse: A paradigm shift in architecture co-design – *Micaela Raposo, Nuno Pereira da Silva, Sara Eloy*

AI-Driven visual generation: Generative adversarial neural network (Gan) and diffusion models – *Pedro Meira-Rodríguez, Vicente López-Chao*

Advancing architectural visualization: Boosting scale and reality with augmented reality – *Chul Min Yeum, Jason Su*

18:30 WELCOMING CEREMONY

Day 3 - December 5

09:00 - 09:30 WELCOME & REGISTRATION

09:30 - 11:00 PAPER SESSION 5

From brush to AI: How tools have transformed architectural paradigms (VC) – *Ashik Vaskor Mannan, M. Arefeen Ibrahim*

On the experience of architectural spaces: A pedagogical experiment using game engines – *Efrosini Charalambous*

Geographic Information Systems (GIS) in architecture and urbanism education – *Joaquim Flores*

11:00 - 11:30 COFFEE BREAK

11:30 - 13:30 KEYNOTE SESSION 2

Wassim Jabi

Syntopy: An integrated approach to geometry, topology, and semantics

Tasos Varoudis

Shapes of intelligible space, or, spaces of intelligible shapes?

13:30 - 14:30 LUNCH

14:30 - 16:30 PAPER SESSION 6

A category-theoretic formalism for architectural design generation: a parametric modelling demonstration – *Anders Ang, Aries Yang, Jielin Chen, Rudi Stouffs*

Leveraging graph-based machine learning to represent and generate architectural layouts – *Anders Ang, Aries Yang, Jielin Chen, Rudi Stouffs*

Assembler – a tool for computational decision at scale in

combinatorial generation of architectural spaces – *Alessio Erioli*

Automated two-story floor plan generation using generative adversarial networks – *Berfin Yildiz, Gulen Cagdas, Ibrahim Zincir*

From text to 3D models: Utilizing Large Language Models in Grasshopper for automating scripting and algorithmic design workflows – *Miltiadis Katsaros, Stella Salta*

16:30 - 17:00 COFFEE BREAK

17:00 - 18:30 PAPER SESSION 7

Connecting spaces and people: Point Cloud segmentation in the context of design anthropology – *Amina Rezoug*

Integratinga additive manufacturing with BIM: A case study in sustainable architecture and construction – *Jaime Cunha*

Nature's integration in architectural ornament through photogrammetry – *Pedro de Azambuja Varela, Francisco Scotti*

18:30 - 19:00 BOOK PRESENTATION

"Emerging Perspectives on Teaching Architecture and Urbanism" and the books of Proceedings of the former editions of the Symposia.

19:30 SYMPOSIUM DINNER

ESPIGA – R. de Clemente Meneres 65

Day 4 - December 6

09:00 - 11:30 PAPER SESSIONS 8 & 9

Comparing anthropogenic water risks from climate change in London and Kolkata – *Tazyeen Alam*

Towards a unified informatic model for cognitive buildings: Integrating BIM, actor models, and dynamic fault trees using digraphical reactive systems – *P Govind Raj, Subrat Kar*

Formal methods in flood disaster response: the case of Porto Alegre, Brazil – *Ana Paula Dalcin, Camilla Pezzica, Clarice Bleil de Souza, Diego Altafini, Guilherme Marques*

ReLighting spaces -Training daylight access cognition in combinatorial spatial assemblages using Reinforcement Learning – A*lessio Erioli, Giuseppe Massafra*

Reassembling waste: Towards a carbon zero built environment – *Inês Caetano, Luis Santos*

Optimizing sustainability through digital tools: Energy and carbon comparative analysis of brick, concrete and wood frame constructions in Coimbra residences – *Leonor Domingos, Sara Parece, Ricardo Resende*

11:30 - 12:00 COFFEE BREAK

12:00 - 13:00 KEYNOTE SESSION 4

Meta Berghauser Pont

Urban morphometrics and Evidence-Based Design

13:00 - 14:00 Lunch

14:00 - 15:00 Keynote Session 5

Franklim Morais

The role of AI in the future of society, the city, construction and architecture

15:00 - 16:30 PAPER SESSION 10

Computational proportional analysis of inner residential spaces in seventeenth-century bastion castles – *Olha Tikhonova*

Exploring variability within 3D shape collections of facade panels of modernist multifamily buildings in new belgrade: A methodological framework – *Djordje Djordjevic, Djordje Mitrovic, Mirjana Devetakovic*

Neuroaesthetic measures of high-rise housing facades – *Audrey Xu, Immanuel Koh*

Kahn's two houses: From formal analysis to animated synthesis – *Heather Ligler*

16:30 - 17:00 COFFEE BREAK

17:00 - 18:30 PAPER SESSION 11

Parametric software and the architectural design – *Bruno Marques, Darlene Julio*

In-formation: shaping tools, composition rules, visual thinking and the creative processes (VC) – *Gonçalo Castro Henriques, Marcio Nisenbaum, Tatiana Teixeira*

Combining space syntax and kernel methods in the delimitation of the Matosinhos Urban Pressure Zone – *David Leite Viana, João Quintão, Rui Fernandes*

18:30 - 19:30 CLOSING SESSION

December 7 - Saturday

10:00 - TOUR: SERRALVES MUSEUM AND GARDENS

14:00 - TOUR: PORTO'S HISTORIC CENTRE

KEYNOTE LECTURES

ADDITIVE CONSTRUCTION ON EARTH AND BEYOND: FROM RESEARCH TO PRACTICAL APPLICATIONS

José Pinto Duarte, Penn State College of Arts and Architecture, Stuckeman School

José P. Duarte *is an architect and researcher, holding a professional degree in Architecture from TU Lisbon and Master's and PhD degrees in Design and Computation from MIT. He currently serves as the Stuckeman Chair in Design Innovation and Director of the Stuckeman Center for Design Computing at Penn State, where he is also a Professor of Architecture and Affiliate Professor of Architectural Engineering. A former Dean of the Lisbon School of Architecture, Duarte co-founded Penn State's Additive Construction Laboratory (AddCon Lab) and X-Hab 3D, a company pioneering mobile 3D printing solutions for the construction industry. Duarte's research explores the intersection of computational design and construction technologies, with a focus on mass customization and sustainable housing. His work leverages additive manufacturing to address the growing global housing demand by developing innovative, context-sensitive design solutions. He co-edited Mass Customization and Design Democracy (Routledge, 2019) and led a team to a 2nd place finish in NASA's 3D Printed Mars Habitat Challenge. Duarte's latest projects include designing 3D-printed, mass-customized homes in extreme environments, such as Alaska, showcasing the practical applications of advanced construction technologies for both Earth and extraterrestrial habitats.*

World population growth and rapid urbanization are driving an unprecedented demand for housing, requiring us to build as many homes in the next twenty years as we have over the past two thousand. This challenge compels us to adopt innovative design and construction technologies, with additive manufacturing emerging as a key solution. This keynote will explore how cutting-edge research and development in construction-scale 3D printing—pioneered at Penn State's Additive Construction Laboratory (AddCon Lab)—are addressing these challenges on Earth and supporting the human exploration of Mars.

The presentation will highlight the synergy between terrestrial and extraterrestrial construction efforts, showing how the lessons learned from designing habitats for Mars can transform how we design and build structures on Earth. Central to this research are three key streams: materials, printing systems, and design, all of which are being developed to create efficient, sustainable, and adaptable construction processes. AddCon Lab's work is advancing across several interdisciplinary research efforts. One focuses on developing sustainable printing mixtures that avoid the use of Portland cement, significantly reducing the environmental impact of construction. Another involves the creation of a mobile printer and a smart nozzle, capable of producing larger, more complex structures with intricate textures, while being easy to deploy and maneuver on-site. Complementing this, a vision-based monitoring system ensures precision throughout the printing process.

On the design front, AddCon Lab is developing a software platform that integrates design patterns with generation, simulation, and optimization tools to support the customization of 3D-printed structures. Other research efforts include strategies for reinforcing walls and developing techniques to print slabs and roofs without formwork.

The presentation will not only cover these advancements but also their practical applications. One example is the design of a house in Alaska, an extreme

environment that poses unique challenges to construction technology. This case study illustrates the adaptability of additive manufacturing to a wide range of environmental and technical conditions, from Earth to Mars.

By integrating innovative materials, advanced printing systems, and novel design approaches, AddCon Lab's research is laying the groundwork for the future of construction, both on Earth and in space. The talk will conclude with a vision for how these technologies, born from the challenges of Mars, could reshape the construction industry, enabling sustainable, efficient, and affordable housing solutions worldwide.

SYNTOPY: AN INTEGRATED APPROACH TO GEOMETRY, TOPOLOGY, AND SEMANTICS

Wassim Jabi, Welsh School of Architecture, Cardiff University

***Wassim Jabi i**s the course director of the MSc Computational Methods in Architecture programme at the Welsh School of Architecture, Cardiff University in Wales. His research interests are in digital design methods, in particular, the use of digital tools in the conception and representation of architectural space, parametric design investigations, building performance simulation, robotics, and fabrication. His main expertise is in parametric design, algorithmic architecture, digital and robotic fabrication, digital lighting, and energy-building simulation. He earned his MArch and PhD from the University of Michigan and taught at various universities in the USA before moving to the UK, in 2008. While teaching in the USA, he secured a National Science Foundation grant as a Primary Investigator. Professor Jabi has published widely on topics ranging from parametric and generative design to the role of light in architecture and building performance simulation. He has authored a book titled "Parametric Design for Architecture" (Laurence King Publishing, London). In 2013, Professor Jabi won funding from the university's internal competitive funding scheme to purchase a large 6-axis high-accuracy industrial robot to investigate innovative digital fabrication processes. His current research is at the intersection parametric design, the representation of space, building performance simulation, machine learning, and robotic fabrication in architecture. Professor Jabi has recently concluded a grant from the Leverhulme Trust as Primary Investigator to study spatial topology in building information modeling (BIM), which resulted in a software library called Topologic.*

This talk explores the concept of syntopy, which emphasizes the systematic integration of geometry, topology, and semantics in architectural design. The presentation introduces TopologicPy, an open-source, AI-powered Python library designed to enhance syntopic spatial modeling and analysis by providing rich, topological, and hierarchical 3D representations of architectural spaces and buildings.

Furthermore, TopologicPy's graph-based structure is presented as a natural fit for the emerging field of Graph Machine Learning (GML). The integration of GML empowers users to classify building typologies, predict associations, and manage large volumes of connected data, thereby streamlining design workflows and decision-making processes. By combining AI, non-manifold geometry, topology, and semantics, TopologicPy provides architects and engineers with powerful tools to model, analyze, and visualize spatial configurations, enabling intelligent decision-making in building design.

SHAPES OF INTELLIGIBLE SPACE, OR, SPACES OF INTELLIGIBLE SHAPES?

Tasos Varoudis, Bartlett School of Architecture, UCL

Tasos Varoudis *is a qualified architect and computing engineer with research focusing on architecture, machine intelligence and spatial computation. He is an Associate Professor in Architecture and Machine Intelligence at the Bartlett School of Architecture, UCL and has a long teaching experience with UCL and AA and a number of international workshops (ACM CHI, Space Syntax Symposium, NTUA).*

Since 2011 he drives the spatial computation and machine intelligence research for the Space Syntax Laboratory at the Bartlett School of Architecture (UCL) where he is developing new methodological and computational innovations combining spatial data-driven models with machine learning and agent-based models.
He leads 'depthmapX' spatial network analysis software that has attracted more than 150000 downloads since its open-source release in 2012.

He co-created and leads the Machine Learning Urbanism Research Cluster 14 (RC14) for the MArch Urban Design and the Spatial Analytics and Computation at the MSc in Spatial Design: Architecture and Cities. His personal research interests are driven by the concept of 'spatial dynamics', the interaction between architectural space and machine intelligence, and are now under the umbrella of the Machine Intelligence Lab.

In this talk, I will explore cutting-edge advancements in Space Syntax and urban network analysis, focusing on the interplay between local surface geometries and long-range urban structure. Traditionally, Space Syntax analyses have relied on simplified representations such as axial lines and street segments. However, these high-level approximations often miss critical details at smaller scales. This keynote will present research that pushes the boundaries of urban analysis by utilizing the highest resolution model of London's 3D geometry to date, created through an extensive LIDAR scan covering 2800 km² of the city.

We'll dive into how local geometries, derived from dense point clouds transformed into detailed several detailed datasets, can be used to predict long-range structural features of the urban network—specifically, measures of network centrality like integration and choice. By applying clustering and unsupervised learning techniques, I'll reveal how local surface features can offer insights traditionally gained from broader syntactical measures. Moreover, I'll discuss our findings on the relationship between local features and global urban movement patterns, with evidence showing that the critical scale for distinguishing between foreground and background networks.

This research opens up new possibilities for understanding urban intelligibility and movement prediction through local-scale analysis, offering an alternative approach to traditional Space Syntax methods.

URBAN MORPHOMETRICS AND EVIDENCE-BASED DESIGN

Meta Berghauser Pont, Chalmers University of Technology

Meta Berghauser Pont is professor of urban morphology and urban design at Chalmers University of Technology in Gothenburg. She leads the research area SMoG (Spatial Morphology Group), which is engaged in research in the areas of urban morphology, space syntax and design theory. Through primarily analytical and quantitative methods, properties of built form are described and its significance for people's (and other species') use and experience of the city is investigated. Meta has published the book Spacematrix. Space, Density and Urban Form (2023) where the concept of density is critically examined. The book specifies the relationship between density and urban form as well as the environmental, economic and social effects of density. In addition to research, Meta teaches urban design. She is also the Head of program for Architecture with responsibility for the educational development of architectural education at bachelor's and master's level.

“The art of architecture is not only to make things beautiful – nor is it only to make useful things, it is to do both at once.” (Hertzberger 1991, p. 174)

In the light of many and urgent urban challenges from climate change, urban inequalities to the loss of biodiversity, the above quote by Herman Herzberger becomes not only more important but requires another approach to both the practice of urban design and the study of urban form.

An evidence base is needed to ensure that design proposals are taking measurable steps to improving urban areas. Further, this evidence must be based on relevant descriptions of the urban environment to be useful in practice. In the keynote presentation at 7FMA, I will make this argument, discuss problems with current studies on cities and present the importance of urban morphometrics as well as the need to broaden what is being included in the study of urban form.

THE ROLE OF AI IN THE FUTURE OF SOCIETY, THE CITY, CONSTRUCTION AND ARCHITECTURE

Franklim Morais, Porto Higher Arts School

Franklim Morais is a civil and electronic engineer, PhD. Professor and Researcher. He was the leader of development teams of private commercial software for scientific applications: pioneering, in the early 1980s, the use of finite element methods for structural engineering on microcomputing; and since the early 1990s developing COTS private hardware and software systems for smart buildings, urban spaces and cities. He is an invited professor in ESAP (Arts University of Porto) Architectural Course since 2001. He participates in LIAD, an academic research team, in a group dedicated to Formal Methods in Architecture.

In a historical environment characterized by several difficulties of economic development, social and international conflicts and serious environmental problems, a new human technology has been presented as pregnant with great consequences for the future – Artificial Intelligence.

As Architecture cannot stay away from this debate, we intend to present a set of reflections on what role AI could play in the development of disciplinary theory and practice.

Regarding the first question, the aspects that change the society in which we live stand out: (a) Economic-social features (productivity, unemployment, reduced working hours, teleworking...) (b) with consequences for the built environment (new occupation of the city, new architectural programs, circulation and autonomous vehicles, new communication interfaces between human beings, city and building...) and (c) construction techniques (accelerated automation, life-cycle treatment...).

Regarding the second, the available AI tools and those necessary for the practice of architecture will be considered and an assessment will be made of their availability and deficiencies.

PAPER SESSIONS

SESSION 1

December 4
10:00
Chair: Paolo Marcolin

***Lais Bertolino** is PhD candidate in Doctoral Program in Spatial Planning at the University of Porto, Portugal, and a member of the Research Centre for Territory, Transports and Environment -CITTA/FEUP. Master in Urban Planning, Architecture and City History of the Federal University of Santa Catarina, Brazil. Architect and Urban Planner with a graduate of the Federal University of Mato Grosso do Sul, Brazil. Professional experience in developing master plans, urban mobility plans and sectoral plans in Brazil.*

***Vítor Oliveira** is the President of the International Seminar on Urban Form (ISUF), Principal Researcher (with Habilitation) at the Research Centre for Territory, Transports and Environ-ment (CITTA / FEUP) and Professor of Urban Morphology and Spatial Planning at UL. He is Associate Editor of 'Urban Morphology', Advisory Editor of 'The Urban Book Series' (Spring-er), Founding Editor of the 'Revista de Morfologia Urbana' (2013-18), and past President of the Portuguese-language Network of Urban Morphology (PNUM). His latest books are 'ISUF, urban morphology and human settlements' (2024) and 'Urban morphology, an introduction to the study of the physical form of cities' (2022).*

***Vinicius M. Netto** investigates cities as networks of segregation, information and cooperation. Presently, his focus is on urban morphogenesis and information signatures as expressions of spatial cultures. He also investigates how societies produce urban configurations as a means to combine seemingly disorganised individual actions into coherent large-scale cooperation systems — a critical recursive process in how societies*

manage tendencies towards entropy. Vinicius is a Principal Researcher at the Research Centre for Territory, Transports and Environment, University of Porto (CITTA | FEUP), Portugal. He is the author of The Social Fabric of Cities (Routledge) and over a hundred articles and chapters.

***Fabiano Lemes Ribeiro** is an Associate Professor in the Department of Physics (DFI) at the Federal University of Lavras (UFLA). He has a bachelor's degree (2002), master's degree (2005) and doctorate (2009) in Physics from the University of São Paulo (USP) with a research scholarship at the Technische Universität (TU) Berlin, Germany. He also has a Post-Doctorate experience (2017-2018) at the City University of London, England. His research interests include Statistical Physics and Complexity Science, with applications in biological, socio-economic systems and city science.*

***Howard Davis** is a Professor of Architecture at the University of Oregon in Eugene. He studied Physics at Northwestern University and received a master's degree in architecture from the University of California, Berkeley, where he worked with Christopher Alexander. His work is focused on sustainable cities deals with the relationships between urban morphology, building typology and the emergence of new forms of the urban economy. He published in the book The Culture of Building (1999). He also collaborated with Christopher Alexander on The Production of Houses (1985). His latest book is "Living Over the Store: Architecture and Local Urban Life."*

***Dries Daems** is an Archaeologist specializing in the Iron Age to Hellenistic Mediterranean. His research interests include social complexity, urbanism, connectivity and information exchange, artisanal production, and human-environment interactions through computational modelling and pottery studies. He is currently Assistant Professor at VU Amsterdam and Visiting Professor at Helsinki University. He has held positions at KU Leuven, Koç University, and Middle East Technical University.*

Caio Cacholas *is a PhD candidate at the Graduate Programme in Architecture and Urbanism, Fluminense Federal University (UFF), Rio de Janeiro state, Brazil. His work is centred on computational simulation, digital urban environments and spatial navigation.*

Daniel Lenz *holds a PhD in Urbanism from PROURB/ UFRJ and a Master's degree in Architecture, Technology and City from UNICAMP, on Performative Architecture, and a bachelor degrees in Architecture and Urbanism (Federal University of Ceará, UFC) and Mechatronics Technology from the Federal Center for Technological Education of Ceará. His work focuses on the relationship between social network topology and urban form based on complexity theory through the development of simulations based on Information Theory applied to architecture, digital materialization and general systems theory.*

Ana Mélice Dias *is a PhD candidate and scholarship recipient in the University of Porto's Faculty of Engineering (FEUP), in the Doctoral Program in Spatial Planning. Her work is focused on the contributions of planning research to practice, having collaborated in academic projects in the fields of sustainable changes to the urban food system, planning support systems for starter cycling cities, and the contributions of urban morphology to territorial management instruments.*

Nuno Gomes *is an Architect and PhD Student and Researcher at CITTA, FEUP.*

Álvaro Costa *is Professor at FEUP, and Researcher at CITTA, FEUP, and CEO of Trenmo which is a Spin-off of University of Porto.*

Miguel Lopes *is Associate Researcher at CITTA, FEUP, and Senior Consultant at OPT.*

PLOT SYSTEMS AND ADAPTATION: A METHOD FOR ANALYSING SPACE AND TIME

Lais Bertolino, Vitor Oliveira

Adaptation refers to the process by which a system is adjusted to environmental conditions, improving both its structure and functioning. In urban studies, this concept is particularly relevant to understand how cities can change to address fundamental challenges. Adaptation of urban systems encompasses the strategies, processes and actions by which cities adjust to improve their resilience and sustainability, as well as the quality of life of their inhabitants. Although the debate on adaptation is quite extensive, the specific role of plot systems in adaptation processes is a recent subject in literature. Briefly, adaptation of plot systems involves reconfiguring the arrangement, use and management of plots to respond to change. This line of research aims at identifying different levels of adaptation of plots in an urban system. A method is proposed to describe and explain plots adaptation. The method offers a quantitative approach to the arrangement of plots in space through accessibility, on plots' functionality considering different land uses, and the management of property rights. This method is tested in one of the world's most vibrant megacities, New York. The evolution of New York's five boroughs over the 21st century is considered. Evidence is gathered showing that some plots are more likely to adapt than others, especially those located in areas of greater accessibility. The recognition of plots' adaptative potential can help improving planning policies, programmes, plans and projects that can better understand space and time.

DECIPHERING URBAN MORPHOGENESIS: A MORPHOSPACE PERSPECTIVE

Caio Cacholas, Dries Daems, Fabiano Lemes Ribeiro, Howard Davis, Vinicius de Moraes Netto

Cities came to be created independently in different world regions at different moments. However, how did the first urban settlements emerge in these different regions? What are the social and spatial conditions and processes that led to the emergence of cities? Are they universal or context-dependent? And what differentiates cities from other types of human settlements in the space of possible configurations? Limited to analysing the evolution of cities in particular historical periods as accretion processes to urban form, most approaches to urban morphogenesis do not answer questions about the fundamental social and material forces driving the city-creation process. This paper addresses such questions through a synthetic approach based on classic morphogenetic theories like Alexander's and Hillier's, concepts in biology such as autopoiesis and morphospace, and the archaeological record. The analysis begins with an archaeological review of the evolution of human settlements from hunter-gatherer societies to urban societies, examining the social and material forces that led to the creation of cities. Key drivers identified include defence, social hierarchies, population scale, food production, commercialisation, and work specialisation, which collectively increased the complexity of the division of labour and drove urbanisation. The study also examines the role of collective learning processes, spatial innovations, and the progressive adaptations that have led to the creation of urban structures. A central theme is the exploration of autopoiesis or structure-seeking growth, where cities arise through interactions

and feedback among their components and agencies. The concept of morphospace is employed to map the space of all possible urban configurations, identifying the transition from potential configurations to those that can support human and urban life in complex societies with a growing division of labour. This involves understanding the non-ergodic nature of urban morphogenesis, where not all possible configurations are explored due to constraints such as material and cognitive conditions historically shaped into different spatial cultures. We investigate the distinctive spatial parameters that define urban settlements compared to non-urban human settlements, exploring three key properties: density, permeability, and entropy of urban form. We develop measures of such properties and apply them to a sample of configurations, from theoretical spatial distributions to actual human settlements, proto-cities and contemporary urban configurations. These properties are used to delineate a morphospace for human settlements, identifying clusters of morphologies that emerge from different parameter sets. Such concepts and empirical content are then used to develop computational experiments on the emergence of local and global structures typically found in urban settlements. By synthesizing insights from urban theory, biology, and archaeology, this approach seeks to elucidate the conditions necessary to transition from potential spatial configurations to those that actually become configurations found in human settlements and, subsequently, urban settlements. Finally, the paper discusses the implications of this morphospace approach for understanding urban morphogenesis and the potential for future research in this area.

CO-LEARNING BETWEEN RESEARCH AND PRACTICE IN PLANNING: ADDRESSING THE PHYSICAL FORM OF CITIES

Ana Mélice Dias, Vitor Oliveira

The exchange of knowledge between research and practice has long been discussed. The gap between two different worlds can be seen in multiple disciplines, including architecture and urbanism. If left unattended, a gap between researchers and architects and planning practitioners will hinder co-learning and collaboration, generating barriers to the betterment of both research and practice in architecture and urbanism. Beyond acknowledging the existence of a gap, appropriate opportunities and methods to promote exchange and learning must be identified. This work proposes a new perspective on existing tools for co-learning and collaboration through a method based on continuous interaction and multidirectional exchanges of knowledge.

Innovation lies in the dual application of the practical and academic perspectives through an increasingly integrative process. In its first stage, this method compares the academic perspective with the views of practitioners, namely municipal planners and consultants. A literature review and semi-structured interviews are focused on conceptions of urban form (relating architecture and urbanism), on how they are put into practice through development control and planning, and on how research is currently involved in this process. For this stage, the diverse territory of the Metropolitan Area of Porto (MAP), in Portugal, is selected as case study. Its 17 municipalities are distinct in terms of geography, land use, urban structure, and planning

approach. This diversity of practices provides information on different ways to relate to research. The interviews confirmed the current discussion in literature by revealing a very pragmatic and numerical view of urban form. This suggests a very restrictive understanding of the potential of morphological theory and concepts. However, the interviews also suggest some room to integrate research into practice through specific planning instruments and tasks. To explore this aperture further, the second stage of the method establishes a participatory observation of planning practices of one of MAP's municipalities, Matosinhos. This provides an opportunity to, not only observe the intricacies of tasks asked of public planners, but also how they apply concepts and methods of research in their daily work. The collaboration extended to different projects of the planning department. The approach for each project followed the same principle, departing from the application of a specific academic method – Morpho (Oliveira, 2013) - to understand the existing urban form and support the development of policies and measures required by each project. By promoting the systematic comparison of academic and practical knowledge on different levels of engagement, this methodology created multiple opportunities for a multidirectional exchange of knowledge. It reveals what are the practical concepts of urban form, as well as the existing administrative, legal and financial barriers to the application of research. Simultaneously, it allows research to adapt to this knowledge and provide more flexible responses, resulting in more useful expertise. In its final considerations, this work raises questions on the types of relationships and projects that can generate this level of co-learning on a consistent basis.

Oliveira, V. (2013). Morpho: a methodology for assessing urban form. Urban Morphology, 17(1), 21–33.

CAN TOPOGRAPHY FAVOUR THE COMPETITIVENESS OF PEDESTRIAN OVER CAR?

Nuno Gomes, Vitor Oliveira, Álvaro Costa, Miguel Lopes

Research on the relationships between urban form and energy demand by transports, shows the impact of several attributes of the physical form of cities on modal split: density, mix of uses, connectivity, to name just a few. However, the effect of an urban form adapted to topography is relatively unknown, because these three elements (urban form, topography, and mobility) are not properly considered together. Often misunderstanding it with slope, literature always presents topography as an obstacle to active modes. This does not mean that topography and slope are being considered as the same thing, but that the only characteristic of urban form somehow affected by topography with energy relevance is slope. This paper argues that there are other features with energy relevance (in addition to slope) that result from the relationship between urban form and topography. In cases where a good adaptation is verified, these other features can be, for example, the proportion of street sections and the whole intricate of an organic urban form with its numerous changes of direction and the consequent reduction of sight distance, as well as the interactions with buildings and urban activities. These morphological features can limit the speed or access of cars. On the one hand, this reduces the competitive advantage of cars when compared to other transport modes, considering the difference in costs. On the other hand, it acts as a structural traffic calming measure, contributing to the safety of pedestrians and cyclists, promoting these options, in contrast to a more ‘artificial’ street layout

demanding for mechanical speeds. The paper proposes a set of structural variables of urban form with influence on car and pedestrian speed. These integrate a GIS-based simulation method, to address large urban areas, encoded directly in networks of edges and nodes or considered in the calculation of routes through an origin-destination matrix based on those networks. The method is applied in two case studies, morphologically contrasting with respect to topography – Salvador in Brazil, and San Francisco in the US. The results suggest that cars have a penalty of travel time that is higher in the organic urban tissue than in contrasting one, compared to the pedestrian. It is thus possible to measure the competitiveness between car and pedestrian in such distinct morphological situations, to conclude that topography may not be an obstacle, but rather a valuable natural resource in a paradigm of energy transition.

SESSION 2

December 4
12:00
Chair: Joaquim Flores

***Nabil Mohareb**, an Egyptian architect and associate professor at the American University in Cairo (AUC), researches the relationship between architecture and urbanism, focusing on the influence of social behaviors on urban spaces. Using methods like space syntax, GIS, and AI, he has published extensively, presented at international conferences, and delivered a TEDx talk. Dr. Mohareb is the Middle East and Africa regional editor for Archnet-IJAR: International Journal of Architectural Research.*

***Ana Cocho-Bermejo** is an expert in hybrid design processes for architecture and urban design based on artificial intelligence. Ana's research focuses on Machine Learning and AI Hybridized techniques for architectural and urban design. Ana holds a PhD in Technology in Architecture from UPC-Barcelona Tech, a MArch from the Architectural Association of London, an MRes in Adaptive Architecture and Computation from the Bartlett, and an MPhil in Artificial Intelligence from Barcelona Tech.*

***Nikola Mitrović i**s a PhD Candidate/Junior Researcher at the Department of Urbanism, Faculty of Architecture, University of Belgrade, Serbia. His research lies at the intersection of urban studies, human geography, and security theory, focusing on the analysis of marginalized pedestrian spaces in a post-socialist context with an aim to develop urban guidelines for that can improve the space in the function of pedestrian movement. He is publishing his research results at various scientific conferences and exhibitions, and participates in international research projects. He also has experience in international workshops.*

Aleksandra Djukić *is Full Professor at Faculty of Architecture, University of Belgrade, Department of Urbanism. Field of professional activities and research is directed on urban design and planning, urban morphology, renewal and heritage. She has published 4 monographies, edited 12 international monographs, 10 papers in SCi journals, more than 200 articles and chapters in international and national scientific journals, books, proceedings. She has participated in numerous national and international research projects and workshops. She has received numerous awards for competitions, in urban practice and research project, and 3 rewards for the best paper at International congresis and published monographs.*

VISUALIZING URBAN EXPERIENCE: AI AND COMPUTER VISION FRAMEWORK FOR HISTORIC COMMERCIAL STREETS IN EGYPT

Nabil Mohareb

Inspired by Bosselmann's pioneering research in analyzing various urban routes through space, time, perception, and memory, this study investigates movement experiences in the historic commercial streets of Alexandria and Cairo. By employing AI and computer vision techniques, we aim to develop a new framework that quantifies the urban scene and links it to movement and visual perception. This nuanced understanding of how urban design influences pedestrian perceptions will lay the groundwork for expanded studies across commercial streets in Egypt and the Middle East, contributing to a comprehensive understanding of urban environments and their impacts on daily life.

SPACE SYNTAX AS AN AGENT BASED SYSTEM. NETLOGO FRAMEWORK PROPOSAL.

Ana Cocho Bermejo, Dave de Jonge

Agent Based System (ABS) features within the NetLogo environment, building upon the foundational work done using UCL DepthMap X. Initially, the research replicates Alasdair Turner's early 2000sexperiments at the Tate Britain to validate the results within this new framework, establishing a base line using the original DepthMap outputs from Turner ad Penn.The methodology progresses by constructing a parallel simulation framework in NetLogo, initially confirming functional equivalence through integration diagrams before introducing key ABS elements—namely agent communication and dynamic attractors in the form of spatial pins in a museum setting. These features are hypothesized to enrich the simulation of spatial dynamics by facilitating more nuanced interactions and emergent behaviors, potentially providing deeper insights into human spatial behavior.A comparative analysis will then be conducted, focusing on the variance in agent behaviors with and without the new ABS features. This will involve mimicking Turner's original analytic approaches to generate path diagrams and aiming to achieve correlations like the R2 correlation of 0.76 reported in Turner and Penn's 2001 study, which validated their DepthMap implementation against actual visitor movements. Findings will show the proposed NETLogo framework is validated by the same correlation,0.89, Turner obtained in 2007 along his research on Through Vision mathematical definition. First implemented proper Agent-based-system features, message passing and goals/ attractors, will show a clear

influence on agents behavior as a priori guessed by Turner in 2011 along his evolved automaton proposal. The study, while not addressing Turner's subsequent proposals on fitness functions andgoal validations due to their unfinished guidelines, sets the stage for further research. It proposes exploring these aspects as logical next steps in enhancing the NetLogo-based space syntax framework. This research not only seeks to validate the integration of ABS features into space syntax studies but also aims to broaden the methodological toolkit available for urban and architectural analysis, paving the way for more dynamic and comprehensive modelling techniques in the field.

ANALYZING THE NETWORK EFFECTS OF VERTICALLY LAYERED URBAN STRUCTURES ON PEDESTRIAN MOVEMENT: A CASE STUDY OF THE MOSTAR INTERCHANGE IN BELGRADE

Aleksandra Djukic, Nikola Mitrovic

As a legacy of modernist principles, there are numerous examples today of designed and planned public and common spaces on elevated levels of layered structures, especially in transport areas or buffer zones between neighborhoods, parks, or parking areas, aiming to separate pedestrians and vehicles. The complex interactions of such spaces with those on the ground level, their impact on patterns of pedestrian movement in the city, and their potential contribution to providing a more livable high-density urban environment are currently not well understood. This paper presents an approach to quantitatively analyze the network effects of vertically layered urban structures on human movement and space use. The Mostar Interchange in Belgrade is considered as the study area, serving as a prime example of a complex system. Different types of users face issues of orientation. Located in the old part of Belgrade, the interchange is a critical traffic hub. The pedestrian underpass is a vital link between two sections of the urban area divided by the highway, significantly impacting the daily lives of the local population. Additionally, this area functions as a public transport or transit area, consisting of bus and tram stations. Furthermore,

this interchange represents urban modernist heritage, which is neglected and raises questions regarding its future development and protection. There are ambiguities regarding whether this transport infrastructure point should be considered a place or a non-place. Groups of individuals, all with the goal of reaching a destination, are termed "momentary communities," but there is insufficient data on how they form, their needs, usage aspects, and how they contribute to shaping the lived experience in this place (or non-place). Despite the interchange's liminal position, it holds hidden values in the daily mobility patterns of users, revealing the life of a pedestrian hub with its rules and problems. To detect the behavioral and movement patterns of pedestrians, a combination of empirical axial line and visibility graph analysis was implemented using the Space Syntax technique, along with empirical observation of pedestrian activities in both static and dynamic contexts. To determine the behavioral patterns of people, four types of observation techniques were adopted: gate counts, static snapshots, movement traces, and people following. Observations were conducted between 4 and 6 pm, which is considered a relatively crowded hour in this specific pedestrian hub. The paper finally discusses the potential of the research approach to inform future urban planning and design of vertically layered public spaces, especially those considered heritage sites with issues of protection and future development. Also, the paper presents the use and application of user simulations in real public open space case studies as a tool for urban design purposes.

SESSION 3

December 4
15:30
Chair: Jorge Viera Vaz

***Mehmet Emin Şalgamcioglu**: after his undegraduate education in Architecture, he is studying in a Master's Program on Urban Design. He has made various observations on street and human interaction. He is enthuastic about working on street art, murals and work on performative art between the context established by the sreet and art. He cares about the place of societies and cultures in the cities' memory. He is aware of the change in the use of the city brought about by human behavior along with sociocultural space.*

***Josep Muntanola** was Chairman of ETSAB-UPC 1980-1984 and Head of the Department of Architectural Design at ETSAB 1996-2010. He is Presidentof the Catalan Academy Beaux Arts de Sant Jordi, Barcelona since 2022.*

***Margaret Krawecka** is a PhD Candidate at ETSAB-UPC. She has a Bachelor of Architecture from the University of Toronto and MA Scenography from Central Saint Marins College of Art and Design, UK.*

Magda Saura *is an Architect and Art Historian. Ph.D. University of California, Berkeley. Senior Professor Barcelona School of Architecture (ETSAB), Polytechnic University of Catalonia (UPC). Research fellow GIRAS International Research Group in Architecture and Society (UPC).*

***Carmen Escoda** is a Professor at ETSAB-UPC in the Department of Graphic Representation of Architecture. Author of works on prestigious Catalan architects such as Enric Miralles.*

Regina Garcia *is PhD Candidate at the School of Architecture in the International University of Catalonia in Barcelona.*

Mauro Costa Couceiro *(Integrated Researcher at ISTAR-IUL-ISCTE Lisbon, Professor Doctor of Architecture by School of Architecture UIC Barcelona) was recently Co-Principal Investigator (Co-PI) at the University of Coimbra (CES-UC), as part of the Santa Cruz Research Project (FCT 30704). This project used advanced technologies to assist in the preservation and virtual reconstruction of UNESCO's architectural heritage. Costa Couceiro's research interests include biomimetics and AI applied to Architecture and Design, with special emphasis on the impact of Extended Reality (XR) and Algorithmic Design technologies in education and professional practice. He also uses these strategies for Mass Customization of Design and Architecture, looking for adaptive and sustainable solutions through robotics (Industry 4.0).*

Carina Vieira de Oliveira*, a Portuguese psychologist, holds a master's degree in Developmental and Educational Psychology from the University of Coimbra. Her research focuses on the positive impact of natural environments on children's development. As a co-founder of the tourism company 'Feel like Heaven' and the initiator of the 'Mães Sem Pressa' project, she advocates for effective parental education practices. Currently, she is devoted to exploring how various environmental layers shape human development.*

Leonor Domingos *holds a PhD in Digital Architecture and is a Post-doctoral Researcher at ISTAR-Iscte and Invited Professor at ISCTE Sintra's Department of Applied Digital Technologies. Her research encompasses building sustainability, energy efficiency, resilient cities, and climate change adaptation through visual programming. Since 2022, she has contributed to three Erasmus+ projects, two Horizon Europe initiatives, and a Digital Skills program.*

Filipa Crespo Osório *graduated in Architecture from the University of Coimbra (DARQ-FCTUC, 2006). She practiced architecture in Barcelona and Lisbon before completing Advanced Studies in Digital Architecture at ISCTE-Instituto Universitário de Lisboa. Her 2020 PhD thesis at ISCTE-ISTAR-IUL, 'Origami Surfaces for Kinetic Architecture,' was FCT-funded. Currently an associate researcher at ISTAR and managing partner at FOLD, she teaches parametric design and digital fabrication at LSD-Lisbon School of Design.*

Mário Ribeiro Manaia *holds a Master's in Architecture and Sustainability from the Polytechnic University of Catalonia (UPC) with distinction, following his Architecture degree from the University of Coimbra. A CIBSE-certified Climate Consultant and European Commission EMSURE (Energy and Mobility for Sustainable Regions) research fellow, he specializes in sustainable design and building performance simulation at UPC. His peer-reviewed research focuses on bioclimatic design and energy efficiency.*

Kaiko Kivi *is a second year PhD student in architecture and city planning at the Estonian Academy of Arts. His research interests are computational methods in the early stage projects, housing configurators, digital fabrication, sustainability, building performance analysis. Kaiko has tutored energy efficiency modelling and digital fabrication. He is a partner in an architecture studio Mudel architects and has founded and participated in several start-up enterprises. He has diverse experience from architectural design, detailing, arts and installations and fabrication.*

THE EFFECT OF POTENTIAL URBAN ELEMENTS ON FINDING DIRECTION IN URBAN SPACE

EXAMPLING OF KADIKÖY-YELDEĞİRMENİ

Buse Erkan, Mehmet Emin Salgamcioglu

Cities have dynamic structures that exist and change with various interactions from the past to present. Living and non-living elements constitute the identity of the city. The role of people living in the city is of great importance in the urban identity. Because the city changes according to the needs and wishes of the people who live in it. These needs and wishes may differ in every region of the city. While cities are affected by people, people are also affected by cities. When analyzing urban space, the type of analysis that has reached from the past to present is urban element analysis. As the most basic example of urban element analysis; Lynch's classification of urban elements can be found. However, when we look at the current conditions, it is thought that it can be interpreted with various additional classifications and recent discussions, as well as some other approaches describing space. Because the city has changed and developed from the past to the present. Such situations change the classification of urban images. In this case, the views of people living in that urban space on the city and the elements they see as the image of the city have also changed and continue to change. In an urban area, people use auxiliary methods when moving from one place to another. The most well-known method brought by today's technology is navigation applications. These

navigation apps are designed so that everyone can find the easiest direction. However, in order to really experience and get to know an urban space, the visual impact and perception established with that urban space are important. First of all, the perceived urban space makes the city that they create individually valuable in the mind. For the first time in this field, cognitive mapping was a study conducted by Tolman(1948) as a psychology experiment. Starting with Tolman, various thoughts and studies on spatial cognition is continuing. Spatial cognition can be defined as a means of transferring representations of the mind. 'Spatial cognition, which as used by the leading developmental psychologist encompass the more specific terms cognitive mapping/ mental maps used both in the environmental behavior literature' (Downs and Stea,1970). With the integration of spatial cognition into cities; it reveals the concept of spatial configuration. "spatial configuration is the primary cause of both attraction and movement in cities" (Hillier et al.,1993). Thus, the dynamics of urban space can be discussed through the concepts of perception, cognition and behavior. The aim of this research is to find potential urban images in the Yeldeğirmeni Neighborhood located in the Kadıköy district of Istanbul, Turkey, as well as buildings, cafes, murals. It is envisaged that a potential map system can be created by integrating the visibility values of the cognitive mapping to be performed in the region with the Syntax2D program and the system prepared via Grasshopper. In this way, it is thought that by revealing the potentials of urban space identity, different maps that constantly improve themselves can be created for city residents.

FORMALIZATION AND EDUCATION IN ARCHITECTURAL AND URBAN DESIGN:
THEIR HERMENEUTIC DIMENSIONS

Carmen Escoda, Josep Muntanola, Magda Saura, Margaret Krawecka, Regina Garcia

Rapid changes in the formalization of architectural and urban design practices and theories demand deep innovation in design education that can modify the way architecture and urban design is produced in the future. Our contribution will begin with a short analysis of the latest theories on how to formalize architectural and urban design, taking into account the impact of artificial intelligence and climate change on human cultures. These theories are based on the works of Paul Ricoeur, Edwin Hutchins and Mikhael Bakhtin, and articulate different disciplines such as anthropology, philosophy, geography, neurology, as well as recent theoretical considerations on the architectural design practices of today. As a second step, we will formalize a methodological framework for analyzing hermeneutic relationships between artistic virtuosity and thinking clarity within design practices, to be considered as structural, chronotopic, space-time articulations. This formalization takes into account both subjective architectural cognitive development, fundamental in education from childhood to adulthood, as well as cultural and historical development, fundamental in any exploration of how architectural and urban design practices and theories work today. The formalization uses chronotopic intersubjective interaction between “voices and points of view” of Mikhael Bakhtin as the key structure, in both the subjective and cultural dimensions of education. We will demonstrate how it works

in two cases: one in children´s constructions of city models and the other in the works of Catalan architect Enric Miralles from Barcelona. Finally, this same formalization will be analyzed in the Garcia Marquez Library, a public building in Barcelona designed by SUMA Architects, where verbal and architectural chronotopic intersubjective interaction interlocates bodies and places, such that using is reading, thanks to the formalization of certain key physical scenarios that support key social functions of “reading”. We will end our contribution with some considerations on the impact of computer tools on the design process, from the educational viewpoint that we have just analyzed. Key differences between brains and machines will be considered and the positive and negative dimensions of this impact will be studied from a hermeneutic viewpoint.

REIMAGINING HUMAN-NATURE COEXISTENCE:
AN INTEGRATIVE APPROACH TO ARCHITECTURAL DESIGN WITH BIOMIMICRY, GENERATIVE MODELING, AND AI

Carina Oliveira, Mauro Costa Couceiro, Leonor Marques Mano Domingos, Filipa Peres Crespo Osório, Mário Ribeiro Manaia

This research project proposes an architectural design methodology that integrates biomimicry, generative modeling, and artificial intelligence (AI) to reimagine the coexistence between humans and the natural environment. The relationship between humans and nature is at a critical juncture due to increasing urbanization and climate change, necessitating a reevaluation of our symbiotic existence. Architecture, as a shaper of our surroundings, has the potential to pioneer sustainable solutions. The proposed methodology is structured around three interconnected phases that operate in a feedback-looping manner, creating a dynamic and iterative process for optimal results:A comprehensive literature review on environmental and developmental psychology, biomimetics, AI, generative modeling, and their architectural applications, identifying opportunities for innovation. Incremental development of computational solutions that integrate biomimetic principles, AI, and generative modeling, enabling us to explore, evaluate, and generate optimized solutions implementation and validation through case studies across diverse scales and architectural typologies, demonstrating the potential for crafting innovative, sustainable projects. It's noteworthy that biomimicry, a method that emulates nature's forms, processes, and systems, provides efficient, adaptable, and resilient solutions. It also incorporates vernacular examples of human adaptation

and the adaptive strategies of our evolutionary ancestors, offering a rich tapestry of insights for innovative design. Additionally, it's important to mention that generative modeling employs algorithms to navigate a vast solution space, pinpointing architectural designs tailored to specific contexts, while AI facilitates decision-making, offering insights into architectural conceptual solutions. The study involved three main phases: Algorithm development for parametric generation of paraboloid structures based on biomimetic strategies guided by proposals developed in collaboration with various AIs. Structural and thermal simulations using various software. Analysis of results, discussion, and suggestion of improvement measures through bioclimatic strategies. The preliminary results demonstrated the effectiveness of the building envelopes in maintaining thermal comfort during the heating and cooling design weeks. However, improvements were suggested, such as increasing the interior thermal mass by adding a variety of mortars to the interior surface of the catenary membrane, installing exterior shutters for shading/fire protection during the summer and considering other passive strategies, such as earth tubes for pre-heating/pre-cooling the air and low-emissivity glazing. The final results, incorporating these improved measures and evaluating the annual energy performance with solutions based on heat pump heating and cooling technologies, demonstrated the effectiveness of the proposed solutions. By addressing contemporary socio-environmental challenges, this research generates innovative solutions, leveraging biomimetic strategies inspired by nature's adaptive wisdom and vernacular architectural culture. The optimized projects strive to enhance human well-being while curtailing environmental impact, steering the transition towards proactive environmental stewardship. The incorporation of human-centered design explorations across diverse contexts promotes a paradigm shift towards harmonious and sustainable human-nature coexistence, while fostering healthy development.

REIMAGINING DIGITALIZED SPACE:
INTEGRATING MEANING AND TECHNOLOGY IN BUILDING SYSTEMS

Kaiko Kivi

Recent research has shown that the integration of AEC disciplines cannot effectively rely on modelling standards constrained by building elements and geometric models. The root of this issue seems to be that for most BIM software primary entities are physical elements such as walls, roofs, and windows, rather than the spaces they enclose. While this approach effectively represents the tangible components of a building, it fails to capture the crucial, yet intangible aspect of space and its properties. This kind of building information aligns well with construction management, as a large part of building economics. However, in the early and later stages of a conceptual project and furthermore the whole lifecycle of the building, its spatial configuration, function, properties, cultural meaning and aesthetics form the core system of information. Failure to relay the wider relationships and dependencies of space can have a profound effect on the effective planning and execution of diverse architectural design development and projects as they get trapped in building-centric digital information. The role of spatial configuration as the essence architectural practice is often overlooked in the realm of digital models. Despite the critical importance of space in architectural design to facilitate social relations, human activities, carry cultural meaning and provide a framework for building components, spatial topology is typically reduced to a secondary or non-existent entity in digital building models. This paper delves into the exploration of this missing dimension of non-manifold

topology of space as a basis of computational design for sustainability, prefabrication, design automation. My research is based on observations and study of sustainable prefabrication of housing over the modernist period until today. The challenge with modular housing has been the lack of flexibility in creating meaningful and reliable proposals and projects, its resilience to sustain economic viability in the face of fluctuations in market demand and fragmented supply chain. Research has surfaced three main obstacles in the complex of incubating configurable building systems. First, how to provide a large enough design space in response to unpredictable market conditions. Second, to be able to integrate all aspects of design and fabrication automation, analysis, and digital information for configuration and reusability of expertise closely enough to reach economic resilience either in scale or flexibility. Third, to ensure that collected knowledge is structured and versioned, accessible for communication across diverse participants, and stored for agile access, reuse, and repurposing. It can be argued that spatial configuration and aesthetics are the aspects of building that should remain non-discursive and exclusive matters of architectural design even amidst the most automated workflows of building and construction. The arrangement of space both within and in the context of human habitation are matters of social practice, reflection, and cultural significance. Therefore, the value of autonomy in the practice of architecture may need alignment within the digital building models and industrial systems, human activities, rather than redefinition of the role itself. Developing a digital information loop for this realignment is the main objective in this ongoing research and experimentation in digitalization.

SESSION 4

December 4
17:30
Chair: David Leite Viana

***Sara Eloy**, Associated Professor at the University of Antwerp (UA), Faculty of Design Sciences. Researcher and Head of the Henry van de Velde research group (UA). Eloy graduated in Architecture (1988) and obtained her PhD in Architecture (2012), both at the Technical University of Lisbon, Portugal. She is an expert in digital technologies applied to architecture design and heritage, namely shape grammar design systems, virtual and augmented reality, and space syntax. Eloy is also working on analysing the building environment, namely considering space perception to achieve a user-centred design and reduce segregation and lack of accessibility.*

***Micaela Raposo** is an architect, MSc in architecture and PhD candidate at Iscte - Instituto Universitário de Lisboa (ISCTE-IUL). She operates in the area(s) of Humanities with an emphasis on Arts, namely in Architecture and Urbanism. Her PhD topic "Housing Co-design: A framework definition based on generative design systems" aims at synthesising the potentials of generative design to address the customization of houses in a co-design process, focusing on user-centred design. Her research interests are digital technologies applied to architectural design and architectural visualisation, housing design, participatory design processes, UX/UI.*

***Nuno Pereira da Silva** is an architect with a Master of Science (MSc) degree in Architecture. He is currently in the final year of his doctoral program and in Architecture at ISCTE-IUL, Lisbon, with the theme "Advancing Construction Technologies: Integrating Human-Machine Collaboration and Drone Robotic Construction in a Comprehensive XR-Simulated Environments*

Methodology". His research focuses on applying robotics and simulation technologies in construction and architecture. His research aims to explore the potential of robotic construction and develop a methodology for their future use in construction.

***Pedro Meira-Rodríguez**: Bachelor Degree in architecture in 2021 from the Universidade da Coruña. Master's Degree in Videogame Design and Development in 2022 from Universidad Complutense de Madrid. PhD student in the Programa Oficial de Doutorado en Novas Perspectivas en Documentación, Comunicación e Humanidades from the Universidade da Coruña from 2023.Research Teaching staff of the Universidade da Coruña in the Civil Engineering Department (September 2023-now).*

***Vicente López-Chao**: Honors Degree of Bachelor of Science in 2011 and in Architecture with the distinction 1st class honors in 2013 from the University College of Dublin. Máster Universitario en Profesorado de Educación Secundaria Obligatoria, Bachillerato, Formación Profesional y Enseñanza de Idiomas in the Universidade da Coruña in 2014. Doctor with international mention and extraordinary award for the Interuniversity Doctorate Program of Equity and Innovation in Education of the Universities of A Coruña, Santiago, Vigo, Oviedo and Cantabria in January 2017 on the environmental quality of educational spaces through interdisciplinary research between architecture and environmental psychology. Máster Universitario en Didácticas Específicas with an extraordinary award from the Universidade da Coruña in 2018. Master's Degree in Representation and Design in Engineering and Architecture with an extraordinary award from the Universidad de Almería in 2019. Doctor from the Programa de Doctorado de Arquitectura y Urbanismo from the Universidade da Coruña in July 2021.*

***Jason Su** is a candidate of Applied Science in the Civil and Environmental Engineering department at the University of Waterloo. He graduated from the University of Waterloo's Architectural Engineering program in 2023, holding a*

position on the Dean's Honors List. His research focuses on augmented reality within the architecture, engineering, and construction fields.

***Chul Min Yeum** is an assistant professor in the Department of Civil and Environmental Engineering at the UW. His main research has advanced computer vision and deep learning for large-scale visual assessment, notably in structure inspection, identifying crucial components and damage from extensive image datasets. To date, he has published over 50 journal and conference papers, with a major focus on vision-based structural health monitoring and post-disaster assessment for civil infrastructure. He currently holds a Discovery Grant and Alliance from NSERC, CFI-JELF, Mitacs Accelerate, HIIFP from Ministry of Transportation of Ontario, and a research partnership with Rogers to develop 5G-enabled smart city applications.*

ARCHITECTING THE METAVERSE:
A PARADIGM SHIFT IN ARCHITECTURE CO-DESIGN

Micaela Raposo, Nuno Pereira da Silva, Sara Eloy

Although already used since the last decade of the 20th century, the concept of Metaverse has gained particular relevance in the last decade due to the advancements of virtual reality, gaming industry and the uptake of big IT companies such as Microsoft and Facebook/ Meta. The integration of the metaverse into architecture design has garnered growing attention and application in practical settings, educational contexts, and scholarly research (e.g., (Kinzler et al. 2022, Tang and Hou 2022, Sopher and Lescop 2023)). The metaverse brings several opportunities for Architecture, such as its global accessibility and adaptive, parametric malleability (Schumacher 2022). Additionally, the metaverse offers possibilities to design and visualise architectural projects in immersive 3D environments and virtual prototyping creation and testing. Added values of metaverse compared to virtual reality (VR) and augmented reality (AR) are the openness of these platforms, their ever-present characteristics, the real-time collaboration among many stakeholders, and the ease of customisation provided. The increased presence enabled in the metaverse also facilitates a more inclusive exploration of spatial contexts that, by the ease of use and clarity, is helpful to both designers and non-designers (Martins and Wolfe 2023). As a social collaboration space, the metaverse empowers architectural design with an "unlimited number of interlinked social experiments taking place simultaneously" (ZHVR Group n.d.). This paper will explore how the metaverse can serve as a collaborative design tool

in architecture, emphasising its capacity for taking multiusers, facilitating real-time interaction, and facilitating participatory design. The paper will examine various metaverse platforms, analyse their features and discuss how they contribute to the architectural design process, namely to co-design processes. Leading metaverse platforms will be systematically analysed, focusing on key features crucial for architectural design, namely, 3D modelling options, customization tools, interaction features, immersiveness, and co-presence. Notable platforms, including Mozilla Hubs, Spatial, and Arkio, among others, will be highlighted. Furthermore, we will exemplify how using a metaverse for three different architectural purposes might be beneficial compared to other more traditional processes in the field, namely VR. The three cases that will be presented involve collaborative design (or co-design), user studies evaluating built environment quality, and simulations of construction processes. By using the Metaverse potential, these cases offer an increased experience in architectural design such as augmented services and digital twins. This exploration aims to showcase the versatility of the Metaverse across different stages of the design process and for diverse purposes. Besides the potentials of the metaverse we will also highlight its shortcomings such as level of realism, internet speed, lack of advanced design features “such as those for analysing building performance, cost, and land use, which are essential for making more informed design decisions during architectural” (Yu et al. 2022, p. 20).While current research primarily emphasises the utilisation of the metaverse in the pre-construction phases of physical buildings, our perspective extends beyond tangible reality. We advocate for developing the metaverse for architectural purposes that exist solely in virtual form. In such instances, as Schumacher highlighted, architects will lead the design of the three-dimensional, immersive virtual environments comprising the metaverse rather than graphic designers (2022).

AI-DRIVEN VISUAL GENERATION:
GENERATIVE ADVERSARIAL NEURAL NETWORK AND DIFFUSION MODELS.

Pedro Meira-Rodríguez, Vicente López-Chao

Although artificial intelligence has been researched since the second half of the 19th century, its relevance has significantly increased in recent decades, especially in the visual arts community due to advancements in image generation technologies. This research offers a theoretical review of visual generation software and its relationship with art and audio-visual production. The main objective is to examine the evolution of text-to-image and image-to-image generative artificial intelligence, highlighting their strengths and weaknesses, and detailing the features of the most popular AI tools in use today. This analysis includes works created from the 2010s to the present using generative adversarial neural networks (GANs) and diffusion models. Sources include scientific databases like Scopus and non-scientific platforms such as LinkedIn, where digital creation professionals frequently share their progress. The study specifically focuses on three leading diffusion models: Dall-E, MidJourney and Stable Diffusion. Each one is assessed independently to explore the communicative abilities, identifying similarities and differences to provide a user guide. This research emphasizes the potential of these AI tools in enhancing spatial and creative design. However, it also stresses the importance of understanding these tools as controlled agents, requiring iterative and informed communication. The complexity of their effective use is highlighted, suggesting avenues for future research into the communicative interactions between users and AI.

ADVANCING ARCHITECTURAL VISUALIZATION:
BOOSTING SCALE AND REALITY WITH AUGMENTED REALITY

Chul Min Yeum, Jason Su

Visualization of concepts and ideas has always been of the utmost importance in the architecture, engineering, and construction industries. Traditional methods of pen and paper drafting helped imagine reality. That soon moved digital with the advent of computer-aided drafting, shifting realism from hand-drawn to picturesque. These digital technologies further prospered with more sophisticated visualization techniques, such as image rendering and later video rendering. With post-processing power now readily accessible, it became constrained by the imagination and creativity of the designer. As technology further pushes boundaries, Augmented Reality (AR) becomes a plausible next step to help architects and designers bring their concepts to life. Already used in various industries such as bioengineering and medicine, AR is slowly emerging as a prospective candidate in architectural visualization. The theme of this paper is to understand the potential that augmented reality possesses for architectural visualization. AR can be utilized to visualize architectural designs in a real-world environment, thereby providing a more immersive and interactive experience for the clientele. By examining the application, this paper seeks to uncover methods and processes necessary for effectively implementing the technology into standard architectural practices. This paper focuses on how AR can address reality and scale which are two common misinterpretations in architectural visualization. Reality can be defined as how surreal the creator's design feels using the chosen medium

and scale is the perception of size and mass others read from the creator's reality. Reality is investigated by leveraging game engines (Unity Game Engine) and imported models (Rhino-8). Game engines promote dynamic rendering that can closely mimic real-world conditions. Importing models allows for the robust shapes and forms intended by the designer. Further integrating functionalities such as real-time lighting and occlusion can expand the sense of realism. Scale will be investigated by the interactive ability of the real scale models placed on the site. On a one-to-one scale, augmented reality has the potential to allow users to visualize designs in their actual environment, providing a unique perspective on size and spatial relationships and harmonization. To demonstrate this potential, we develop an AR application (app) for iPhone, enabling users to position architectural models in any given location. Using this app, we visualize a student-designed pavilion structure within a local park setting. We conduct a comparison of the scale and realism of the model visualization, contrasting it with a 3D computer model.

The results demonstrate that AR visualization can provide a more authentic sense of size and spatial relationships, effectively bridging the gap between digital visualization and real-world experience. This technology opens up new possibilities for architects, designers, and stakeholders to assess and experience designs in a more intuitive and immersive manner, ultimately leading to better-informed decision-making processes.

SESSION 5

December 5
09:30
Chair: Bruno Marques

Efrosini Charalambous *holds a diploma in architecture engineering from the National Technical University of Athens, a master's in advanced architecture from the Institute of Advanced Architectural of Catalonia and she was awarded a PhD in Architectural Space, Spatial Cognition and Behavioural Neuroscience, from the Bartlett School of Architecture, University College London (UCL). Her research interests are primarily focused on the study of human spatial and architectural experience, embodied-enactive cognition, and wayfinding behaviour using mobile EEG (electroencephalography) and VR technology. Within this context, she is particularly interested in both quantitative and qualitative approaches to human experience within the built environment (including urban emotions and well-being urban policies) as well as dynamic system theories and complexity, urban theory, human geography and smart city technology. She has been a teaching and research fellow at several departments of the Faculty of the Built Environment at UCL (BSA, CASA, IGP) and an adjunct lecturer at the University of Cyprus and Frederick University. She is a registered architect at ETEK(CY) and she has practised architecture in Athens and Barcelona. She has received recognition as an Associate Fellow of the Higher Education Academy for her teaching practice as well as the UCL Education Award in 2018.*

Ashik Vaskor Mannan*, Senior Associate Professor in Architecture at AIUB, has been teaching since 2006. With a B.Arch. from BUET (2001) and an M.Arch. from DIA Bauhaus (2006), he has published extensively on architecture, philosophy, and AI-driven design. A principal at Studio XI*

Architects, he began his career with Metaphor Architects and has earned accolades such as the 2004 IAB Award. His research spans cultural theories and AI applications in creative fields. Internationally active, he leads workshops, including with DigitalFUTURE on computational design and AI. Recognized for bridging academic and professional domains, he contributes to shaping the architectural discourse.

M. Arefeen Ibrahim *graduated from Bangladesh University of Engineering and Technology (BUET) in 2001, earning a Gold Medal for his outstanding academic performance in Architecture. He received the prestigious F.R. Khan Scholarship too and completed his MS in the USA in 2004. Ibrahim began his teaching career at North South University before joining American International University-Bangladesh (AIUB) in 2007, where he currently serves as Head of the Architecture program. He is the Principal Architect at archiWORKS Consultants. His research interest focuses on architectural history, urban design, and digital architecture. He also served as Secretary-Education at the Institute of Architects Bangladesh (IAB) from 2019-20 & 2021-22.*

FROM BRUSH TO AI:
HOW TOOLS HAVE TRANSFORMED ARCHITECTURAL PARADIGMS

Ashik Vaskor Mannan, M. Arefeen Ibrahim

The evolution of architectural drawing tools has profoundly shaped the way architecture is conceived, designed, and executed. From hand-drawn plans using brush and ink during the Renaissance to the sophisticated digital tools of today, these instruments have been decisive in both the craft and language of architectural practice. In earlier times, the use of brushes and hand-drafting techniques influenced the very lines of architectural plans, guiding the creative process. The introduction of Computer-Aided Design (CAD) in the late1960s was a monumental change, providing architects with the ability to produce precise, editable designs, drawings more efficiently. The subsequent transition to 3D modeling and Building Information Modeling (BIM) tools revolutionized not only visualization but also collaboration across multiple disciplines. Today, emerging technologies like Artificial Intelligence (AI) and generative design offer architects the ability to optimize designs based on a variety of criteria, parameters including sustainability and material efficiency. As architectural tools continue to evolve, they fundamentally alter the design process, influencing the craft of plans and shaping the broader paradigms of architecture. What begins as a progressive tool can become conservative over time, as architecture itself mutates in response to technological and cultural shifts. This paper explores the historical and contemporary impacts of these tools, demonstrating how they continue to redefine the craft of architecture and the future possibilities they offer.

ON THE EXPERIENCE OF ARCHITECTURAL SPACES: A PEDAGOGICAL EXPERIMENT USING GAME ENGINES

Efrosini Charalambous

The impact of the built environment on human perception, cognition, behaviour and experience has been the central topic in 'Environment- Behaviour' (E-B) studies since the 60's when architectural practitioners started exploring ways to integrate scientific or research-based knowledge into the design practice. New advanced technologies such as virtual reality and biosensing open up the space of possible inquires, offer opportunities to understand better the brain-body-environment relationship. This sort of knowledge can be valuable in research-informed design practices. However, there are several obstacles along the road, including the necessity for adequate knowledge and skills to evaluate critically the relevant literature. One way of enhancing architects' skill set on formal methods is by introducing relevant teaching material in architectural education. This can be, for example, through courses that familiarises students with scientific approaches while giving room for them to imagine more designerly modes of doing science. For example, the idea of architecture as experience has been a key issue in the work of many architectural theorists (e.g. Juhani Pallasmaa, Tonino Griffero, Alberto Pérez-Gómez). Game engines and virtual reality enable architects to perceive the spatial qualities of their architectural proposal though a first-person experience of moving and walking through their architectural designs. They constitute valuable tools in examining the potential impact that specific architectural elements or spatial situations

may have on perception and action (e.g. changes in affordance, peripheral vision, atmosphere). Consequently, game engines offer a unique opportunity to explore the multisensory lived experience of architectural space and to compare the potential impact of different architectural solutions on, for example, behavioural patterns. The paper discuss the development and results of an academic course focusing on the use of game engines as digital tools for design inquires focusing on the first-person experience and perception of architectural space. The aim of the course was to familiarise third year undergraduate architectural students with the use of game engines in the field of architecture as well as to introduce them to the idea of experimental designs and hypothesis testing. Student were guided along the process of using 3D Rhino models to set up a virtual reality environment in Unity 3D game engine as well as collecting and representing and evaluating (visual comparison) data related to participants' movement patterns within these virtual environments.

GEOGRAPHIC INFORMATION SYSTEMS (GIS) IN ARCHITECTURE AND URBANISM EDUCATION

Joaquim Flores

Integrating Geographic Information Systems (GIS) into the teaching of architecture and urbanism has emerged as a transformative approach. While traditionally used by geographers and urban planners for regional and urban development, GIS offers a wider range of applications in architectural education and research. This includes urban design, sustainable development, architectural heritage management, and fostering a more comprehensive understanding of the built environment within its social and natural context. More recently, the integration with Building Information Modelling (BIM) and the ability to create 3D environments and print them from GIS, enhances the potential use of this software in the student's future professional practice.

This paper explores the pedagogical benefits and challenges of incorporating GIS technology into architecture and urbanism curricula. By leveraging GIS, students gain proficiency in spatial data management, visualisation, analytical techniques, and decision-making, and create detailed, data-driven models of urban and architectural environments, which are crucial for addressing complex urban issues and enhancing design outcomes. In educational settings, GIS fosters a deeper understanding of geographic context, environmental impact, and the dynamic nature of urban systems.

The paper presents the experience of more than ten years of GIS teaching in Architecture and Urbanism compared with case studies from various academic

institutions, highlighting innovative teaching methodologies, project-based learning, and interdisciplinary collaborations. The findings underscore the importance of GIS in equipping future architects and urban planners with the skills needed to navigate and shape the built environment in the digital age, addressing complex urban challenges in an increasingly data-driven field.

The discussion also addresses the need for updated educational frameworks, faculty training, and access to technological resources to fully realise the potential of GIS in architectural and urbanism education.

This research contributes to the ongoing discourse on formal methods in architecture and urbanism, advocating for a more balanced, integrated and technology-driven approach to architectural design and urban planning education.

SESSION 6

December 5
14:30
Chair: Franklim Morais

***Rudi Stouffs** is Dean's Chair Associate Professor in Architecture and Assistant Dean (Research) in the College of Design and Engineering, National University of Singapore. He received his PhD in Architecture from Carnegie Mellon University, an MSc in Computational Design, also from CMU, and an MSc in Architectural Engineering from the Vrije Universiteit Brussel. He has held previous appointments at CMU, ETH Zurich, and TU Delft. His research expertise and interests include computational issues of description, modelling, and representation for design, in the areas of shape recognition and design generation, building information modelling and analysis, virtual cities and digital twins.*

***Anders Ang** is an M.Arch graduate from the National University of Singapore, an architectural designer and researcher. His approach to research and design is deeply rooted in the study of the discipline's history, drawing from past theories and works to innovate for the future. This pursuit has expanded into exploring philosophy, industrial design, computer science, and Artificial Intelligence, pushing the boundaries of architectural design with a multidimensional approach.*

***Aries Yang** is an M.Arch graduate from the National University of Singapore and a researcher at Singapore ETH Centre. With a profound passion for architecture, buildings, graphic design, drawing, and painting, Aries has five years of experience in the field and recently completed the M.Arch program. His keen interest in computational tools for the built environment is reflected in his focus on parametric design and design automation, particularly utilizing machine learning and*

deep learning techniques. Post-graduation, Aries joined the school as a research assistant, dedicated to studying the relationship between new technologies and the built environment.

***Jielin Chen** is a PhD candidate in Architecture at the National University of Singapore. She obtained her MLA (Distinction) from the University of Hong Kong and a BEng in Urban Planning from Zhejiang University. Her research specializes in design computing, with a focus on computational methods for design representation space interpretation. She is dedicated to disentangling computational design representation and seeking innovative solutions to complex architectural design research challenges. Her accolades include the Young CAADRIA Award 2021 and the SDSC Dissertation Research Fellowship 2022. She currently serves as the peer reviewer of IJAC and AIEDAM.*

***Alessio Erioli:** University of Bologna Researcher/ Assistant Professor, MArch in Biodigital Architecture, PhD in Architectural Engineering, Co-de-iT co-founder. His interests regard the theoretical and applied consequences of computation as a design medium in architecture and related fields, focusing on autonomy/intelligence/agency in the design process. He is also skilled in computational design, programming & modelling on several platforms.*

***B.Yıldız** works on machine learning and deep learning at ITU Informatics in Architectural Design program.*

***G.Çağdaş** is a professor in the field of Informatics in Architectural Design.*

***J.Zincir** is a doctoral faculty member at IEU ,working on data mining, machine learning and network security.*

***Stella Salta**, an architect and computational designer based in Athens, is currently pursuing her PhD at NTUA School of Architecture. She holds an M.Sc. in Data Science and Machine Learning, in addition to an M.Arch. and a Diploma in Architecture Engineering. Her research focuses*

on integrating advanced computational methodologies and generative algorithms into architectural design. Currently, she is exploring methods to harness Artificial Intelligence and Large Language Models in Architecture. Her aim is to enhance the comprehension, accessibility, and democratization of machine learning techniques within the field, encouraging their adoption across various architectural practices.

***Miltiadis Katsaros** is an Associate Professor at the School of Architecture, N.T.U.A., where he heads the Acoustics Research & Simulations Laboratory. His interests range from building tectonics, optimization methodologies and artificial intelligence, to energy efficiency and acoustics. Alongside academia, as co-founder of M2K architects, he contributes insights from research to real-world projects, including sustainable designs and historic restoration. This dual role allows him to bridge theory with practice, fostering a deeper understanding of architecture's impact on our built environment.*

A CATEGORY-THEORETIC FORMALISM FOR ARCHITECTURAL DESIGN GENERATION:
A PARAMETRIC MODELLING DEMONSTRATION

Anders Ang, Aries Yang, Jielin Chen, Rudi Stouffs

In the realm of architectural design, efficiently and effectively translating abstract design concepts into tangible 3D CAD models without extensive iteration remains a grand open challenge. This significant bottleneck is predominantly due to an absence of methodologies capable of encapsulating design logic within computational models effectively. The result is a hampered ability to freely explore alternative designs or manipulate design concepts across projects efficiently. At the core of this challenge lies the intricate task of capturing and manipulating the design reasoning process—a critical component yet to be fully addressed within existing digital design tools. Addressing this challenge requires the development and application of innovative methodologies. We propose Compositional Neural Patterns (CNP) as a blueprint aimed at not only addressing but transcending these limitations by drawing upon the compositional nature inherent in architectural design—viewed through the lens of Category Theory, a mathematical tool grounded in compositionality. CNP is structured around three foundational conceptual components: Design Objects, Design Morphisms, and Design Compositions. Harnessing category theory's power of abstraction, these components enable the representation of design elements, design logics and their interactions

in a novel, computationally exploitable manner. This theoretical groundwork allows us to reimagine building blocks ('design objects') and their interactions ('design morphisms'), laying out compositions that directly map thought-to-construction sequences otherwise mired in iterative cycles.While we are envisioning a deployment strategy that involves conjoining the theoretical foundation with deep learning, in this study we demonstrate CNP through a prototype plugin built in Grasshopper for Rhino3D. The prototype is designed to showcase how design objects in the formalism may be expressed, and how instances of design objects can be combined through certain compositions of design morphisms to generate 3D CAD models. The prototype is designed to be a proof of concept for the formalism, and not necessarily a fully functional tool, as we anticipate the use of GNN-based neural algorithmic reasoning to embed complex building ontologies and represent them into actionable design logic, learned and generalized from design precedents. In the paper, we narrow our study to considering site, spatial organization grid, and massing as design objects, and demonstrate their representation, interactions, and composition using Skidmore, Owings & Merrill's (SOM) 1952 Lever House as an iconic example of a typical office building and a significant milestone in modern architectural history. The building is a prime example of a conventional building and, as such, an ideal candidate for an initial testing of the prototype. Specifically, we will demonstrate the potential of CNP using the prototype Grasshopper plugin to generate a 3D CAD massing model of the Lever House and variants thereof. We will present our insights from this demonstration and reflect on future work.

LEVERAGING GRAPH-BASED MACHINE LEARNING TO REPRESENT AND GENERATE ARCHITECTURAL LAYOUTS

Anders Ang, Aries Yang, Jielin Chen, Rudi Stouffs

Unveiling the mystery of design reasoning has long been a holy grail in the field of design research and it largely remains an open issue. In terms of abstraction, the design reasoning process is a constant analytical process that maps certain objectives to others through an iterative endeavour. In the realm of architectural design, particularly at the conceptual phase, architects rely on a mix of manual abstract methods—ranging from textual descriptions to 2D and 3D sketches to achieve this endeavour. This traditional approach facilitates ”see-move-see” cycles as articulated by Donald Schön, enabling rapid ideation through visual evaluation. However, these methodologies encounter limitations when transitioning concepts into detailed 3D CAD models, leading to significantly time-consuming iterative processes. Furthermore, typical 3D CAD models represent buildings as-is, and do not capture the design compositional logic that brought about the result, nor allow for manipulations of the design through its design logic. This lack of design reasoning representation in 3D CAD models hinders the rapid exploration of design alternatives and the replication of design concepts. We argue that the utilisation of graphs as relational data offers a significant advantage in this context, especially multi-layered graphs in the context of Graph Neural Networks (GNN). The concept of multi-layered graph aligns with the architectural design process, where different layers can represent different aspects of the design, such as structural elements, spatial configurations, and

functional relationships. However, according to Melanie Mitchell, the compositional reasoning capacity of abstract concepts is something that contemporary AI systems have not yet mastered in any general way. Thus, to achieve our intended goal, new model prototypes need to be explored and experimented with. In this paper, we describe an iterative experimentation process undertaken to develop a generative graph model capable of synthesizing building footprints. The objective is toleverage graph-based machine learning to represent and generate architectural layouts that adhere to realistic urban planning constraints. Specifically, we explore the capabilities of Deep Generative Models of Graphs (DGMG) and of the Generative Pre-trained Transformer (GPT) within this context. The DGMG framework is a well-established approach in the field of molecular structure generation, and adapting it to architectural layouts presents a novel exploration of its utility. DGMG utilizes a Recurrent Neural Network for sequential decision-making during the graph generation process, allowing for graph generation in a controlled and structured manner. Building on the seminal work of Yoon et al. (2023) on the Computation Graph Transformer (CGT), we extend the capabilities of autoregressive generative models, notably the Generative Pre-trained Transformer (GPT), to the domain of graph Generation by reimagining the input representation and sequence processing mechanisms of the traditional GPT model for the specific challenges presented by graph data. We will describe our results and emphasize our findings, both positive and negative, towards achieving our goal.

ASSEMBLER – A TOOL FOR COMPUTATIONAL DECISION AT SCALE IN COMBINATORIAL GENERATION OF ARCHITECTURAL SPACES

Alessio Erioli

Assembler is a computational tool developed for the design and study of assemblages in architecture, with focus on the generation of heterogeneous space via combinatorial growth: duplicated parts from a limited set are iteratively added together following heuristics sets (connection rules and choice criteria). The aim of its larger conceptual framework is to mobilize degrees of distributed, autonomous computing for the generation of heterogeneous and scalable spatial assemblages able to support a multiplicity of programmes that can change over time. Combinatorial design here refers not to its mathematical/ theoretical formulation, but to an established algorithmic/ procedural method for the generation of heterogeneity through repetition, searching for complexity by arrangement of a limited set of repeatable basic parts. Key figures in the theorization of this process are the likes of Stiny and Alexander, as well as several architects who used proto-algorithmic and combinatorial methods (such as Wright, Team X, Dutch Structuralists, Friedman and others in the second half of the XX century). Despite its undeniable potential (both computational and generative), the presently available implementations as computational tools focus almost exclusively on parts, relying on random choice

or predefined patterns for rules policy (thus hindering respectively control and adaptability), with little to no record of relations and system topology. Drawing from the concept of assemblage in DeLanda's formulation, Assembler focuses on the importance of both parts and their mutual, topological relations in the formation of emergent qualities, allowing computation at the local, regional, and global scales. Parts and connections are conceptualized as computing objects representing respectively the geometry of reserved space and its connectivity capabilities, with the possibility to decide how that space is occupied by data (both numerical and geometrical - i.e. architectural elements) at the scale of the part and/or the assemblage, leveraging contextual information via part/whole/environment relationhood. The design process is understood as a decision network, where intentionality (as know-how) can be encoded in procedures and criteria. Assembler utilizes iterative, rule-based deterministic criteria, where the parts themselves are computing elements able to perform operations that inform the assemblage growth at each step. The user has control over the design of parts and connectivity, the heuristics of the system (from included presets to programmable ones), and the design of environmental information encoded as a discrete tensor field. The outcome is a structure of data-populated voids, in which geometrical, topological and numerical data is available and accessible at any point, in order to connect the outcomes to other analytical/computational tools and strategies. Granular computation and decision making at each iteration are furthermore open to integration with bespoke processes and methods for both computing the state of the environment and parts, and the criteria for parts and/or rule selection (including the potential implementation of Deep Reinforcement Learning strategies for the training of goal-based policies).Assembler is developed as a plugin for the Rhino+Grasshopper environment, including a .NET .dll library for custom programming in C#.

AUTOMATED TWO-STORY FLOOR PLAN GENERATION USING GENERATIVE ADVERSARIAL NETWORKS

Berfin Yildiz, Gulen Cagdas, Ibrahim Zincir

The design of two-story floor plans presents a unique set of challenges in architecture especially in the context of automated generation. Unlike single-story layouts, two-story configurations introduce additional complexities related to vertical circulation, spatial organization, and structural considerations. One of the main challenges in the automatic generation of two-story plans lies in capturing and synthesizing the complex relationships between the different levels of the building. Addressing this challenge, this study explores the application of Generative Adversarial Networks (GANs) for automating the generation of two-story floor plans. This study aims to streamline workflows and unlock new creative potential for architects and designers using artificial intelligence. The methodology employed in this study involves several stages. Firstly, a comprehensive dataset of existing two-story floor plans is compiled, encompassing a diverse range of layouts, and spatial configurations. Then, a GAN architecture is developed and trained using the dataset. This involves the use of convolutional neural networks (CNNs) to extract meaningful features from floor plan images and generative networks to synthesize new floor plans. The training process is iterative; while the generator network learns to generate realistic floor plans, the discriminator network provides feedback to guide improvement of generator output. Finally, the trained GAN model is evaluated using quantitative measurements and qualitative evaluation. Preliminary results indicate the feasibility and effectiveness of the proposed

GAN-based approach for two-story floor plan generation. The trained model demonstrates the ability to generate a variety of floor plans that exhibit similar characteristics to those in the training dataset. It has been observed that the created floor plans successfully include appropriate vertical circulation layouts that connect both floors. These stairs effectively fulfil their functional role by providing efficient vertical circulation between floors. However, analysis of spatial quality indicators reveals a scarcity of design elements that encourage different visual relationships, such as gallery spaces. Overall, the findings offer promising results as one of the first multi-floor studies for the integration of GANs into architectural design workflows. The integration of GANs into the process of two-story floor plan generation represents a significant advancement in the field of architecture and design automation. By leveraging the capabilities of artificial intelligence, architects and designers can expedite the design process, explore a broader range of design possibilities, and iterate more efficiently. However, challenges such as model scalability, diversity of generated designs, and user control over the generation process require further research. Overall, this study contributes to the ongoing dialogue on the intersection of artificial intelligence and architectural design, offering insights into the potential of GANs to reshape the future of design process.

FROM TEXT TO 3D MODELS: UTILIZING LARGE LANGUAGE MODELS IN GRASSHOPPER FOR AUTOMATING SCRIPTING AND ALGORITHMIC DESIGN WORKFLOWS

Miltiadis Katsaros, Styliani (Stella) Salta

The integration of artificial intelligence (AI) into architectural design represents a paradigm shift with profound implications for design automation. This paper explores the integration of Large Language Models (LLMs) within the Grasshopper plug-in using Python, aiming to automate workflows in algorithmic design. By harnessing the natural language processing capabilities of LLMs, architects can automate intricate design tasks and expedite ideation processes with unprecedented efficiency. This discussion comes at a pivotal time, as AI and LLMs are transforming how we interact with knowledge, emphasizing the importance of prompt engineering and the art of asking the right questions to unlock the full potential of these powerful models. While current research at the intersection of design and AI primarily focuses on LLMs' applications in generating photorealistic images through prompts, there is a significant lack of exploration regarding their implementation in other design workflows, particularly in parametric design and the production of 3D models. This paper aims to address this gap by introducing a framework that utilizes LLMs and prompt engineering within Grasshopper, aiming to empower architects with AI-driven design tools that enhance automation, efficiency, and algorithmic thinking in architectural practice. By leveraging domain-specific knowledge, our objective is to translate textual design concepts into parametric 3D models using Grasshopper as an intermediary platform. The methodology involves three key steps: (a)

Prompt Engineering: setting up guidelines for crafting prompts that encapsulate design intents and constraints, tailored to effectively guide LLMs in generating Grasshopper scripts, (b) Script Generation: utilizing LLMs to interpret these prompts and generate Grasshopper scripts that translate high-level design concepts into executable code, creating 3D objects that meet prompt requirements, and (c) Debugging and Iteration: enabling dynamic adjustments to design parameters based on real-time feedback, fostering an iterative design process that adapts to evolving requirements. To enhance LLM performance, four prompt engineering techniques will be employed, including Retrieval-Augmented Generation (RAG) to integrate domain-specific information, Chain of Thought (CoT) to break down complex queries, the ReACT Method for iterative refinement, and Domain-Specific Prompting (DSP) to ensure accurate outputs. Two case studies will be conducted to demonstrate the effectiveness and limitations of the proposed framework in translating design ideas into parametric 3D models via prompting. The integration of LLMs into parametric design workflows promises to significantly streamline the design process, reduce manual coding efforts, and facilitate rapid ideation and iteration of architectural outputs, marking a transformative shift in how design workflows can be automated and optimized. By effectively communicating design intentions through refined prompts, architects can harness AI to produce high-quality 3D models efficiently. This approach not only enhances creativity and efficiency but also paves the way for unforeseen innovations in design automation.

SESSION 7

December 5
17:00
Chair: David Leite Viana

Amina Rezoug *is a faculty member at Istanbul Bilgi University. She graduated from Middle East Technical University, Department of Architecture in 2008. She earned her MS. Arch in Architectural Design and Computation Program from ITU with her thesis "Fast, Cheap & Adaptable: A Digital Model for Designing Temporary Post-Disaster Housing." She completed her Ph.D. in the same institution with her dissertation "A Visual Method of Analysis for User Modifications in Climat de France." She was a visiting researcher at the Faculty of Architecture of Porto Digital Fabrication in 2019. She has been involved in the conception and construction of many architectural projects of different scales. Her work has been presented at exhibitions and conferences in different countries. She has taught interior architecture and design courses and studios at different levels since 2016. Her research focuses on decolonial approaches combined with formal methods and computational research. She is particularly interested in housing and dwelling issues in controversial contexts such as post-disaster, marginalized mass housing, and post-colonial modern housing. Her research therefore is highly inspired by cultural studies, design anthropology and decolonial theories.*

Francisco Scotti *studied architecture at the University of Porto and received his master's degree in 2024. He spent a year on an exchange program at the University of São Paulo, where he had the opportunity to intern at HUS Architects. He is interested in other cultures and how they influence architecture, which led him to study languages such as Italian and Japanese. He enjoys exploring digital fabrication tools,*

particularly 3D printing, and parametric design programs like Rhino Grasshopper.

***Pedro de Azambuja Varela**, an architect interested in the intersection of mathematics and constructed form, graduated from FAUP in 2006 with a thesis on elliptical spaces in religious architecture. After working in Vienna and New York, he pursued advanced studies at FAUP and founded AZVAvisuals in 2012, specializing in graphic and web design, programming, and 3D modeling. He has contributed to significant projects, including the FCT research project on robotic technology in architecture, and earned a PhD focusing on stereotomy and modern technologies.*

***Jaime Cunha** holds a Double Master's degree in Architecture and Sustainability. Worked eight years at Rogers Stirk Harbour + Partners (RSHP) in London and Madrid, contributing to diverse projects worldwide.*

Currently, Jaime is a researcher and lecturer with expertise in sustainable architecture, BIM, and 3D printing technologies. He is a PhD candidate focused on reducing CO2 emissions in construction through additive manufacturing, exploring design and materiality for a more sustainable built environment.

CONNECTING SPACES AND PEOPLE:
POINT CLOUD SEGMENTATION IN THE CONTEXT OF DESIGN ANTHROPOLOGY

Amina Rezoug

Point cloud segmentation plays a crucial role in a wide range of applications, including semantic information extraction, object recognition, and human tracking. It involves the organization of unstructured point cloud data into distinct subsets to facilitate further analysis. The segmentation of point clouds is vital for understanding 3D scenes and has attracted significant attention from researchers. The advancement of deep learning and deep neural networks has notably enhanced the accuracy and efficiency of point cloud segmentation. In this paper, we propose a novel integration of point cloud segmentation with design anthropology to enrich its influence on design practices, making them more humane and "decolonized." Design anthropology emphasizes the significance of theory and cultural interpretation, integrating contextualization and interpretation into design tasks. This approach contrasts with the traditional design focus on creation and innovation by systematically exploring the past to comprehend the present and future. Through ethnography, anthropology provides a unique sensitivity to the value orientations of various groups impacted by design projects, including disempowered groups and segregated communities. By integrating point cloud segmentation into design anthropology, we can promote a human-centered approach that considers cultural and socioeconomic contexts. This methodology can enhance our comprehension of the relationship between users, spaces, and architecture beyond conventional 2D representations such as

drawings and photographs. While there is a potential risk of point cloud segmentation being manipulated by repressive authorities, this paper seeks to examine its potential for fostering connection, repair, and sustainability among the built environment and its community.

INTEGRATING ADDITIVE MANUFACTURING WITH BIM:

A CASE STUDY IN SUSTAINABLE ARCHITECTURE AND CONSTRUCTION

Jaime Cunha

Automated manufacturing (AM) and Building Information Modeling (BIM) are transformative technologies that are reinventing the architecture, engineering, and construction (AEC) industry. This abstract investigates the integration of BIM in the optimisation of the design process, focusing on energy efficiency verification, material optimisation, CO2 reduction through Lifecycle Assessment (LCA) and Lifecycle Costing (LCC). Furthermore, it highlights the case study designed and prototyped by OODA and HAVELAR built by 3D Printing Construction (3DPC), demonstrating the practical applications of these technologies. The Integrated Project Design process is developed using BIM methodology as a digital framework for designing, constructing, managing, and monitoring the building lifecycle. This centralizes data and facilitates collaboration among stakeholders, ensuring efficient, accurate, and sustainable design processes. The plug-in “Green Building Studio” enhances the energy performance of the proposed design, integrating an energy analysis to enable detailed simulation of energy consumption related to insulation, ventilation systems, lighting, and building orientation. This enhances thermal comfort and reduces heating and cooling demands. These simulations assist in identifying design solutions that maximize energy efficiency and minimize operational costs..To identify the materials used in the construction, the

plug-in OneClick LCA provides insights into the environmental performance of the applied materials, identifying the carbon footprint. Incorporating Lifecycle Assessment (LCA) tool evaluates the environmental impact of materials throughout their lifecycle—from production to disposal—enabling the selection of materials with lower embodied energy and CO2 emissions. Lifecycle Costing (LCC), on the other hand, analyses the total cost of materials over their lifecycle, including initial costs, maintenance, and end-of-life disposal, ensuring cost-effective and sustainable material choices. The prototyped house built by Havelar in Porto District in 2024, using 3DPC techniques, showcases a diverse possibility of additive manufacturing technologies. This residential unit, designed with a strong focus on sustainability by the materials selected and the design optimisation. BIM was used to improve the design for energy efficiency, incorporating passive solar heating, high-performance insulation, and energy-efficient glazing. Energy simulations ensured that the design minimized energy consumption while maximizing comfort. Material optimisation was achieved through the LCA and LCC analyses, facilitated by BIM. Sustainable materials with low embodied energy were selected, such as cork granulate for insulation between walls. The 3DPC was optimised to reduce waste and emissions through material calculations and automated layering minimised construction waste and improved efficiency. By today, the case study has been monitored with various sensors which will provide an overview of the humidity and temperature inside and outside. Developing this case study will improve the architecture and construction by creating highly efficient and sustainable buildings. By optimising design processes, verifying energy efficiency, conducting thorough LCA and LCC analyses, and enhancing thermal performance, this approach points a more sustainable and innovative future.

NATURE'S INTEGRATION IN ARCHITECTURAL ORNAMENT THROUGH PHOTOGRAMMETRY

Francisco Scotti, Pedro de Azambuja Varela

Contemporary architecture has witnessed a shift from the machine-driven de-ornamentation of the 20th century to a resurgence of ornamentation. In this context, many architects embrace mimesis, using computers to generate natural forms. This research proposes leveraging photogrammetry, with its accessibility and capability to 3D scan intricate shapes, as a method for integrating nature into architectural ornament. Contemporary architecture is moving towards an ever-increasing complexity, driven by technological development, especially digital fabrication tools. Ornamentation is a means of expressing this complexity, offering a moment of sculptural freedom in a field ruled by structure and function (Kolarevic & Klinger, 2013). Unlike the modernist movement's pursuit of de-ornamentation, contemporary digital tools have facilitated re-ornamentation in architecture. However, this reappearance manifests in new forms distinct from the tradition, categorized by Antoine Picon into pattern, texture, and topology (2013). Furthermore, with the advent of digital tools, architects can become digital artisans, controlling both the design and manufacture of ornament (Spuybroek, 2016). Since architecture often draws inspiration from nature, recognizable throughout all its history and, more recently, with movements like biomorphism, this work proposes the use of 3D scanning to reproduce natural forms in architecture, instead of generating them digitally. Among various 3D scanning technologies, photogrammetry stands out due to its accessibility, utilizing overlapping photographs to

generate a point cloud that can be converted into a mesh (Luhmann, 2013).Several experiments will be conducted to translate natural objects into architectural elements, using different digital fabrication techniques such as 3D printing, laser cutting and milling. The experimentation is going to be divided according to the type of ornament being explored into three parts: VOLUME, RELIEF, and PLANE. The first part will focus on the ornamental expression of large volumes, like the shape of a whole building, while investigating the technical limitations in preserving three-dimensional details from scanning to fabrication. The second part will study the use of photogrammetric models as relief of surfaces, transforming meshes into seamless textures that can be applied to various shapes. Lastly, the transformation of scanned objects into two-dimensional ornamentation will be explored using various techniques such as depth maps or halftones. This research will analyze the viability of photogrammetry as a creative tool in the current context of architectural re-ornamentation. As architecture continues to evolve alongside technological advancements, the insights gathered in this study will provide a solid foundation for future research into the creative possibilities offered by photogrammetry in architectural design.

Kolarevic, B., & Klinger, K. (2013). Manufacturing Material Effects: Rethinking Design and Making in Architecture. Routledge.Luhmann, T. (2013). Close Range Photogrammetry: 3D Imaging Techniques (2nd ed.). De Gruyter.Picon, A. (2013). Ornament: The Politics of Architecture and Subjectivity. Wiley.Spuybroek, L. (2016). The Sympathy of Things: Ruskin and the Ecology of Design (2nd ed.). Bloomsbury Academic.

SESSIONS 8 & 9

December 6
09:00
Chair: Sérgio Mendes

***Tazyeen Alam** has submitted her doctoral thesis with Prime Minister Research Fellow, the most prestigious fellowship awarded only to top 8% researchers in India. She is puruing her doctoral degree at Ranbir and Chitra Gupta School of Infrastructure Design and Management, Indian Institute of Technology, Kharagpur, India. She has achieved various reputed publications and international participation in her research tenure and recognized globally. Her area of research includes Urban Planning, Urban Morphology, Sustainable Cities and Communities, Household Water Use, Statistical modelling and Mixed methods for urban assessments. She has a bachelors degree in Architecture and a master's degree in Urban Regeneration*

***P Govind Raj** is a PhD student at the Indian Institute of Technology, Delhi, specializing in Formal Methods for designing, developing, and analysing Cyber-Physical Systems, particularly Cognitive Buildings. He is also the Co-Founder of Liberin Technologies, where he leads the engineering team. With nearly two decades of experience in the IT industry, he has worked with government R&D institutions and startups.*

***Subrat Kar** graduated with honors in Electrical & Electronics Engineering from Birla Institute of Technology & Science, Pilani in 1987, and earned a Doctoral Degree in Electrical Communication Engineering from the Indian Institute of Science, Bangalore in 1991. He was a Post-Doctoral Fellow at the International Center for Theoretical Physics, Trieste (1991-1994). Currently, he is the Ram and Sita Sabnani Chair Professor at the Department of Electrical Engineering, Indian Institute of Technology Delhi. His*

research focuses on optical communication, telecom protocols, embedded systems, and high-speed networks. He holds patents in sensor networks, routing algorithms, and telecom protocol design.

***Diego Altafini** is a UKRI/Marie Skłodowska-Curie Postgraduate Fellow, working at the Welsh School of Architecture, Cardiff University in decision support systems for informed decision-making within the DECIDE Project (MSCA/UKRI Grant no.101107846-DECIDE/EP/Y028616/1). An urban analyst with experience in economics, network analysis, and urban planning, he is interested in exploring the technical aspects of multi-domain models, focusing on territorial imbalances, to provide stakeholders with outcome-driven solutions for urban-regional issues. Expert in multidimensional and multi-scale urban regional digital simulations and visual representations, integrated into the study of human-space-economics interactions within cities and regions, with over a decade of experience in Geographic Information Systems.*

***Camilla Pezzica**, Lecturer in digital methods in Architecture and Urbanism at the Welsh School of Architecture, Cardiff University, is an urban analyst and environmental designer interested in interdisciplinary research with a focus on sustainable development and disaster risk reduction, housing and urbanisation, urban morphology and transformations, transitional urbanism and public space. She has expertise in multi-scale and multidimensional urban modelling and analysis, digital simulation and design methods, and in the study of human-space interaction in cities and buildings.*

***Clarice Bleil de Souza** is a Professor at the Welsh School of Architecture, Cardiff University working in decision-making in the built environment. Interested in exploring interdisciplinary aspects of decision-making including models and modelling applied to the areas of conventional design, sustainable design and regenerative design, she has done extensive work in user-centric building performance simulation and its integration throughout the design process*

in her teaching and research. She has interests in decision-making for urban regeneration, decision-making in emergency, disaster management and post-disaster relief, decision-making in designing for harsh climates as well as decision-making in participatory design processes including low-income communities.

***Ana Paula Dalcini** ia a Post-Graduate Researcher affiliated with the Instituto de Pesquisas Hidráulicas (IPH), Universidade Federal do Rio Grande do Sul (UFRGS). She has her Ph.D. (2023) in Water Resources and Environmental Sanitation from the Institute of Hydraulic Research (IPH) at the Federal University of Rio Grande do Sul (UFRGS). Visiting researcher at the University of California - Merced (2023). Graduated in Environmental Engineering at the University of Caxias do Sul (2010). Experienced in the field of Water Resources Management and Sanitation, hydroeconomic modelling, reservoir operation optimization, environmental flows, ecosystem services restoration, and systemic analysis of multiple water uses.*

***Guilherme Marques** is a Professor affiliated with the Instituto de Pesquisas Hidráulicas (IPH), Universidade Federal do Rio Grande do Sul (UFRGS). He has expertise in the development and application of systems analysis tools to water resources planning and management. The focus is on finding solutions to improve adaptation capacity of water systems, addressing operational and economic efficiency under uncertainty. He has participated and coordinated both research and consultation projects involving collaboration in Brazil, Chile, United States, Kenya, France a Canada. Field of work and interest includes modelling large-scale water systems for decision support on planning and management.*

***Giuseppe Massafra** is a Student in Architecture and Engineering at Alma Mater Studiorum University of Bologna (Italy). His resarch focuses on combinatorial methods for generating spatial assemblages with adaptive control over climate and environmental factors. His interests interweave computational design and Reinforcement Learning.*

***Alessio Erioli**: University of Bologna Researcher/ Assistant Professor, MArch in Biodigital Architecture, PhD in Architectural Engineering, Co-de-iT (www.co-de-it.com) co-founder. His interests regard the theoretical and applied consequences of computation as a design medium in architecture and related fields, focusing on autonomy/intelligence/agency in the design process. He is also skilled in computational design, programming & modelling on several platforms.*

***Luis Santos** holds a PhD in architecture (UC Berkeley) and is an Associate Professor at the Department of Architecture, Design and Media Technology (CREATE) at Aalborg University, Denmark. His research links building science with generative and parametric design particularly in the fields of building energy performance, daylight, indoor environmental quality and lately in buildings' carbon footprint through their entire life cycle. Architecture pedagogy using gamification and building performance simulation tools is also central in Dr. Santos academic efforts.*

His extensively published in such subjects in high quality peer-reviewed journals and international conferences as well as serving in peer-review processes.

***Inês Caetano** is a PhD in architecture who has been researching methodologies to support the use of algorithmic design (AD) approaches in the design, analysis, and realization of building façades. Her scientific contribution to this field includes 11 journal papers, 5 book chapters, and 18 conference papers. Meanwhile, she has collaborated with the AEC industry, supporting design studios in developing nonstandard facade designs through AD. Since 2023, she has also been working at BUILT CoLAB as an AD specialist, aiding national companies in their digital transition by developing solutions to close the gap between laser scanning and BIM technologies.*

***Leonor Domingos** is a PhD Arch (since 2022, specialized in Digital Architecture), post-doc and Integrated Researcher at ISTAR-Iscte and Invited Professor at the Department of Applied Digital Technologies*

of ISCTE Sintra. Her research is focused on building sustainability assessment, energy efficiency, resilient cities, building adaptability for climate change, visual programming and digital transformation and education. She started working as an architect in Lisbon in 2017, and has recently been focused on research and education. Leonor has worked since 2022 on three Erasmus+ projects (already finished), two Horizon Europe (on-going) and one Digital Skills programme (on-going) as a team member, and worked for funding proposals.

***Sara Margarida Parece** is a PhD student at Iscte-IUL and a research assistant at Iscte-ISTAR. Her research is funded by a grant from the MIT Portugal Programme. Her work involves studying digital tools, such as BIM, to facilitate the transition to the Circular Economy in the construction sector, sustainable design practices, and the efficiency of building materials.*

***Ricardo Pontes Resende** is an Assistant Professor at ISCTE – Instituto Universitário de Lisboa, specializing in sustainable construction and digital transformation in the Architecture, Engineering, Construction, and Operation (AECO) sectors. He holds a Ph.D. in Civil Engineering from the University of Porto (2010), an M.Sc. in Structural Engineering (2003), and a B.Sc. in Civil Engineering (2000) from the Technical University of Lisbon. His research focuses on Building Information Modelling (BIM), Virtual and Augmented Reality, and IoT in construction. Dr. Resende is the coordinator of the Bachelor in Applied Digital Technologies and Sustainable Built Environment at ISCTE.*

COMPARING ANTHROPOGENIC WATER RISKS FROM CLIMATE CHANGE IN LONDON AND KOLKATA

Tazyeen Alam

Despite their geographical disparities, researchers occasionally consider London and Kolkata similar due to shared historical significance and colonial legacies. Both cities have diverse populations, fostering parallels in exploring multiculturalism, migration, and urban challenges.
It is crucial, however, to recognize and respect the unique characteristics that differentiate each city and shape their trajectories.
This paper presents a comprehensive comparative analysis of water risks arising from climate change in two distinct urban contexts—London, United Kingdom, and Kolkata, India. As both cities grapple with the escalating impacts of a changing climate, this study focuses specifically on the diverse challenges related to anthropogenic water interactions. London, characterized by its temperate climate and advanced infrastructure, stands in contrast to Kolkata, a tropical cyclone-prone region with unique socio-economic dynamics. In London, the primary risks emanate from increased flooding, changes in precipitation patterns, and heightened urban heat stress affecting water demand.
The study examines the effectiveness of adaptive measures employed to address these challenges, including sustainable drainage systems and resilient water supply infrastructure. Additionally, it assesses the impact of climate-induced water stress on the city's water quality

and distribution. Alternatively, Kolkata confronts risks associated with cyclones, rising sea levels, and coastal water impacts, exacerbating water scarcity and quality issues. The paper investigates the adaptive capacity of Kolkata's water management strategies, considering socio-economic constraints, increased urban water demand during heat waves, and the intricate challenges of saltwater intrusion into freshwater sources. The paper aims to contribute to a refined understanding of climate change impacts on water resources in diverse urban settings due to human interactions. Therefore, the findings of this study not only enhance the academic discourse on climate change and urban water risks but also offer practical insights for policymakers, urban planners, and water resource managers navigating the complexities of climate adaptation in two markedly different urban landscapes.

TOWARDS A UNIFIED INFORMATIC MODEL FOR COGNITIVE BUILDINGS:
INTEGRATING BIM, ACTOR MODELS, AND DYNAMIC FAULT TREES USING BIGRAPHICAL REACTIVE SYSTEMS

P Govind Raj, Subrat Kar

This paper extends our previous work on the Actors@ BIM framework by introducing a tower of informatic models for cognitive building by leveraging Building Information Modeling (BIM), Actor Model of computation and [[Dynamic Fault Trees]] (DFTs). We envisage that as buildings become smarter and software-intensive there will be requirements to formally capture various aspects of a cognitive building and understand and analyse them using formal methods. This paper's primary contribution is the unification of these three models through the use of a common formal meta-modelling framework of the Bigraphical Reactive system. This will enable the different models to be merged as a coherent whole to model future Cognitive Buildings. The key contributions of the paper are as follows: (a) We provide a framework for Modelling cognitive buildings by utilizing three different models each addressing a unique concern within the cognitive building ecosystem namely: BIM for structural, design and architectural-related concerns, Actors as a model for defining the behaviour of the cyber elements like sensor, computers, actuators, and communication elements within the cognitive buildings and Dynamic Fault Trees which can capture and model safety and reliability aspects within the cognitive building. Our Modelling technique offers a significant advantage over other formalisms like Petri Nets

and State Machines. By using a common meta-model of BRS to represent BIM, Actors, and DFTs, we enable interaction among these models which was previously difficult to achieve. Further, this integration allows us to utilize a unified set of tools for the formal Verification of various design concerns and aspects of cognitive buildings, streamlining the Verification process across different domains. (b) We present the formal Semantics of Dynamic Fault Trees (DFTs) using Bigraphical Reactive Systems (BRS). To the best of our knowledge, this is the first instance of BRS being employed to model DFTs. (c) We formally verify the semantics of various gates of Dynamic Fault Trees, including PAND, POR, FDEP, SEQ, and SPARE, as presented in this paper. (d) We detail the software architecture and Integrated Development Environment (IDE) built around our tower of informatic models, offering Domain Specific Languages (DSLs) for each formalism within the model. This IDE facilitates formal verification of design scenarios using tools like BigraphER and model checkers such as PRISM. The paper includes examples demonstrating the practical application of these verification tools within the IDE.

FORMAL METHODS IN FLOOD DISASTER RESPONSE:
THE CASE OF PORTO ALEGRE, BRAZIL

Ana Paula Dalcin, Camilla Pezzica, Clarice Bleil de Souza, Diego Altafini, Guilherme Marques

More recurrent due climate changes, flooding events are the main cause of urban disasters in Brazil, resulting in extensive infrastructural, economic and life losses. In the late April of 2024, very intense rains have drenched the state of Rio Grande do Sul, in southern Brazil, triggering the worst disaster ever recorded in the country in terms of number of municipalities affected and people dislodged, submerging entire towns, sweeping entire blocks and greatly disrupting the road-circulation network between Porto Alegre, the state capital, and its surrounding metropolitan region. As Brazil is heavily dependent on road-transport, these interruptions conveyed challenges in emergency response and early recovery actions, that required prompt efforts oriented to data production and communication. In that regard, formal methods, such as configurational analysis, played an important role in providing meaningful information about the state of the system after the disaster, guiding first-responders and decision-makers in prioritizing road-elements for protection to avoid system collapse, and identifying accessibility lifelines throughout the road-network. This paper provides an account of these efforts, as GIS-based and Configurational Analyses were used to examine the state of Porto Alegre's Metropolitan Area road-circulation network structure before and after the May 2nd - 10th 2024 floods. The analysis focuses on three subsequent moments corresponding to the situation on: 28th April (pre-disaster, preparation); 6th May (disaster, emergency response); and 10th May (immediate post-disaster, early recovery). The road-network graph of the

pre-disaster system was set-up using OSM data, which was then intersected with GIS flood footprint geodata, locally verified by the Hydraulic Research Institute (IPH-UFRGS). Moreover, the dataset comprising the early recovery phase was drawn based on the information provided by the Porto Alegre's Prefecture. The three cases are compared to highlight how the grid was affected by the large-scale flooding event and its overall performance after the disaster and during early recovery. The diachronic analysis is based on a quantitative and qualitative assessment of, respectively, Normalised Angular Integration (NAIN) and Normalised Angular Choice (NACH) distributions. For visualising the effects at different spatial scales, NAIN and NACH are modelled both for local and global radii: 400, 800, 1,200 meters for local pedestrian movement; 2,000 and 5,000 meters, for local vehicular movement; and Rn, topologic, for vehicular movement within the whole system. Results reveal changing hierarchies in movement patterns concerning both Relative Accessibility and Preferential Routes' Choice. Subsequently, it is demonstrated how these simulations were integrated into a pilot Decision Support System, co-designed through engagement with local stakeholders, to provide early responders and decision-makers information about network changes useful to identify which road-elements should be preserved to avoid a larger system collapse. While highlighting the potential value of formal methods, particularly configurational analysis, in generating meaningful information for supporting emergency management operations, the paper concludes by presenting an account of limitations that currently affect the swift adoption of the approach by local actors. Additionally, it outlines promising future research avenues to better integrate configurational analysis into outcome-driven Decision Support Systems.

RELIGHTING SPACES
TRAINING DAYLIGHT ACCESS COGNITION IN COMBINATORIAL SPATIAL ASSEMBLAGES USING REINFORCEMENT LEARNING

Alessio Erioli, Giuseppe Massafra

This research aims to enhance a combinatorial process for the generation of spatial assemblages with adaptive control over climate-related factors, such as daylight access, by means of Reinforcement Learning (RL). In combinatorial design, a finite set of parts and rules for their coupling and iterative aggregation, generates larger assemblies whose properties, performances, and functions, at different system scales, differ from those of the constituent parts; the whole is composed of multitudes, engendered by the mutually occurring interactions. A key role in establishing the potential for the emergence of holistic qualities lies in the design of both parts and rules as well as in the policy that regulates rule selection in relation to the design goals. Combinatorial design is defined by Sanchez as an inherently open process, where no kind of optimization is achievable. However, it is possible to operate within this context to create systems whose holistic properties, related to quantitative aspects of the architectural space, follow predetermined design criteria. In their combinatorial research, both Sanchez, Alexander (in "A Pattern Language"), and Stiny (in his study on "Shape Grammars") use fixed criteria (either stochastic or heuristics-based) for the choice of aggregation; a different strategy is using a reward-oriented policy to derive the aggregation rule to apply at each iteration. From this perspective, Makoto Sei Watanabe in his Induction Cities series experimented with "inductive" models: a wide range of viable spatial configurations generated via a stochastic process coupled

with selective target conditions based on climatic factors such as direct sunlight access (Sun God City).Building on Watanabe's work, this study aims to bind combinatorial logic with topological considerations and environmental-climatic feedback, for the context-adaptive generation of spatial units assemblages with control over daylight hours access on exposed surfaces. The approach uses RL-trained agents instead of random choice/heuristics iterative algorithms to adapt to lighting conditions in the process of selection and aggregation of parts. The agents move and place parts (voxels) within a voxelized space, aiming to ensure topological consistency and a target daylight hours access on exposed surfaces in the final assembly. The research introduces condition-based adaptivity into a combinatorial process by means of RL training, moving beyond both random choice and predetermined heuristics sets; although both can relate to boundary conditions, they are respectively non-controllable and tied to a specific environmental scenario. Through the agent's trained policy, the system learns a state-action-reward relationship in a process of continuous feedback between space, environment and climate data that applies to any environmental configuration that can be coded in the system's terms. The study is implemented coupling state-of-the-art Python RL libraries (Stable Baselines 3, Gymnasium) and the Rhino+Grasshopper environment for modelling, daylight factor calculation, and visualization, building a custom infrastructure for bidirectional data communication between computing environments during the training and inference phases.

REASSEMBLING WASTE:
TOWARDS A CARBON ZERO BUILT ENVIRONMENT

Inês Caetano, Luis Santos

The decarbonisation of buildings is becoming critical in the face of irreversible anthropogenic climate change impacts. Life Cycle Assessment (LCA) allows to holistically analyse buildings' carbon flows by considering the following stages: Stage A - manufacturing and construction; Stage B - operational use; Stage C - decommission and demolition; Stage D – reuse and upcycle potential. Stage C is responsible for significant carbon emissions and thus crucial in the design of low-carbon emission structures. Furthermore, stage (D) was recently added to the LCA methodology and includes reusing building material waste to offset the final building's carbon footprint. Although 54% of LCA studies in buildings consider their end-of-life (stage C), only 11% include stage D, partially due to the lack of approaches that facilitate the design process of reusing old building parts in new construction. The paper tackles the challenges of buildings' end-of-life by studying the carbon offsets of upcycling building waste materials in the design of new building envelopes. It also examines the emerging tectonic potential in reassembling waste in building design. The objective is to explore ways to creatively upcycle demolition waste materials in architectural design and, therefore, mitigate the environmental impact of new structures within the boundaries of a city or bioregion. To that end, we present a novel generative design system (GDS) that assists architects in efficiently repurposing building material waste in new façade designs. The GDS combines algorithmic

design approaches, LCA tools, e.g., BOMBYX [5], and whole-building energy simulation. The application of the proposed GDS entails the following steps:

- Decomposition of an existing building into reusable parts: the system processes the envelope of an existing building into an atlas of reusable parts.
- Reassembly of reusable parts: the GDS aids architects in developing new building envelopes using disassembled building parts whilst considering specific criteria, e.g., window-to-wall ratio.
- Global Warming Potential (GWP) estimation: we use an LCA approach that includes stage D to calculate GWP expressed in CO2-eq of the generated designs based on European standards and in the work of Van Gulck et al..

In the full paper, we put the GDS to the test in a real-world scenario. Our case study involves reassembling building parts from a future demolition site, Sundparken, in Horsens, Denmark. We use the system to maximise existing material stock reuse in developing different facade solutions for a set of predefined building masses. The solutions generated by the GDS are then compared in terms of GWP and energy use intensity. This practical application of the GDS showcases its potential for use in design processes that aim for low-carbon emission buildings. Finally, the full paper discusses the potential of the proposed approach to usher in a new tectonic era, one that embraces the concept of waste.

OPTIMIZING SUSTAINABILITY THROUGH DIGITAL TOOLS:

ENERGY AND CARBON COMPARATIVE ANALYSIS OF BRICK, CONCRETE AND WOOD FRAME CONSTRUCTIONS IN COIMBRA RESIDENCES

Leonor Domingos, Sara Parece, Ricardo Resende

The use of Grasshopper for conducting energy simulations and embodied carbon analysis in architectural design is increasingly prevalent due to its flexibility and integration with other design and analysis tools. This study focuses on a residential house in Coimbra, Portugal, comparing the performance of traditional brick, concrete, and wood frame construction. The primary objectives are to evaluate energy efficiency and quantify embodied carbon for each construction type, and conduct a comparative analysis. Grasshopper, a parametric design plug-in within Rhinoceros 3D, enables detailed and iterative modelling and analysis. For this project, Grasshopper was integrated with Ladybug and Honeybee, plugins that facilitate environmental simulations and energy analysis. Additionally, the Embodied Carbon plugin for Grasshopper was employed to assess the carbon footprint associated with each construction method. Traditional construction methods in Portugal predominantly use bricks and concrete, known for their durability and structural integrity. Wood frame construction, although less traditional in Portugal, offers the benefits of reduced weight and the potential for lower embodied carbon due to the renewable nature of wood. The energy simulations were conducted using plug-ins LadyBug and Honeybee,

which utilize EnergyPlus as the simulation engine. Key performance indicators included annual energy consumption for heating and cooling, thermal comfort levels, and peak energy loads. The house's geometry, orientation, and local climate data were input into the model to ensure accuracy. Results from the energy simulations revealed distinct differences between the construction methods. The traditional brick and concrete construction demonstrated moderate thermal mass, resulting in some reduction in temperature fluctuations and peak heating and cooling loads. However, it exhibited higher overall energy consumption due to less effective insulation properties. The wood frame construction showed the highest energy efficiency, with superior insulation reducing both heating and cooling demands. Embodied carbon analysis was conducted by calculating the amount of material used in the construction. Traditional brick and concrete construction had the highest embodied carbon, primarily due to the extensive use of cement. Wood frame construction exhibited the lowest embodied carbon, attributable to the renewable nature of wood and lower energy requirements during production. The comparative analysis highlights the trade-offs between energy performance and embodied carbon. Traditional brick and concrete construction, while beneficial for durability and structural integrity, incurs high operational energy costs and embodied carbonWood frame construction stands out for its low embodied carbon and superior energy efficiency, making it a viable option for sustainable building practices. In conclusion, this research demonstrates the effectiveness of Grasshopper in conducting comprehensive energy and embodied carbon analyses. For the Coimbra house, wood frame construction emerged as the optimal choice for minimizing environmental impact while enhancing energy performance. This research underscores the importance of integrating advanced simulation tools in the design process to inform sustainable construction decisions. The findings contribute to the growing body of knowledge on sustainable building practices and provide valuable insights for architects and engineers aiming to reduce the environmental footprint of residential buildings.

SESSION 10

December 6
15:00
Chair: Bruno Marques

***Olha Tikhonova**, Ph.D., is a Ukrainian scholar focusing on fortifying history and restoring cultural heritage. She was an assistant professor and Marie Skłodowska-Curie fellow at the Polish Academy of Sciences (Warsaw) from 2022 to March 2024 and joined the University of Seville in May 2024 at the same type of scholarship. Dr. Tikhonova is a Scientific Expert Member of the European Federation of Fortified Sites and The Fortress Study Group. She earned her Ph.D. cum laude from the Lisbon School of Architecture and has held multiple international scholarships. Her expertise includes architectural theory, conservation, urban analysis, space syntax, and GIS.*

***Djordje Mitrović** is an architect, a PhD student, and a Teaching Assistant in the scientific discipline of Descriptive Geometry and Geometry of Architectural Form at the Department of Architecture, Faculty of Architecture, University of Belgrade, Serbia. His research focuses on photogrammetry-wise digital reconstruction and semantic enrichment of as-built geometry as well as on parametric and algorithmic design, especially in the role of reverse engineering. He actively participates in scientific conferences and exhibitions and holds a certificate for unmanned aircraft piloting across the entire territory of the Republic of Serbia.*

***Djordje Djordjević**, Associate Professor, employed at the University of Belgrade - Faculty of Architecture. Teaches academic courses Architectural Geometry 1 and Architectural Geometry 2. Active both: in his scientific work referred to Descriptive Geometry, Architectural geometry, Visual Illusions noticeable in architectural-urban spaces,*

CAD and BIM, including Architectural Photogrammetry and in his professional activities that relate to computer-guided 3D modeling/visualization and digitization in various domains, especially in the fields of architecture and urbanism. Actively takes part in related non-teaching activities: faculty- and non-faculty-wise.

***Mirjana Devetaković** teaches BIM (Building Information Modeling) as an associate professor at the University of Belgrade, Faculty of Architecture. She is a member of the Laboratory for examination, valorization, protection and presentation of cultural heritage. Her research interests include documentation of built heritage, especially HBIM (Heritage Building Information Modeling), as well as digital twins usage in heritage protection.*

***Immanuel Koh** is an Assistant Professor in Architecture & Sustainable Design (ASD) and Design & Artificial Intelligence (DAI) at the Singapore University of Technology & Design (SUTD).*

***Audrey Xu** is a senior landscape architect at Singapore's Housing & Development Board (HDB).*

***Heather Ligler** is an architect, design researcher, and faculty of the School of Architecture at Florida Atlantic University, where she is an Assistant Professor. Her scholarship engages shape grammars, rule-based design, and design history/theory to question how formal approaches and emergent technologies in design can help us imagine the future of architecture (and reimagine the past). Heather received her Ph.D. and M.S. in Design Computation from the School of Architecture at Georgia Institute of Technology and her dual Bachelor of Architecture / Bachelor of Interior Architecture degrees from Auburn University.*

COMPUTATIONAL PROPORTIONAL ANALYSIS OF INNER RESIDENTIAL SPACES IN SEVENTEENTH-CENTURY BASTION CASTLES

Olha Tikhonova

In the study of seventeenth-century fortifications, the geometric precision of military architecture has often overshadowed the residential spaces within bastion castles. This research aims to bridge this gap by applying proportional analysis to the inner spaces of a bastion castles, demonstrating that the principles of Renaissance architecture were not limited to grand villas and palaces but also permeated the residential areas of military structures in the Renaissance. By utilizing computational methods to analyze room proportions, we confirm that the architectural elegance of Palladio's and Serlio's designs influenced the layout of living quarters within these fortified environments. This article presents a detailed workflow for analyzing architectural proportions within a given layout. The analysis identifies the closest standard proportions for various rooms based on their bounding boxes. The methodology combines Python libraries for mathematical computations and JSON for data input handling, leveraging the Grasshopper addon for Rhinoceros to work with pre-modeled spaces in CAD and visualize the results. Conclusions are drawn based on the proportion errors to determine the alignment of room dimensions with classic architectural ratios, which are visually highlighted by the code in the Rhino window. This workflow and code can be applied to analyze the inner voids of any palace or residential space, providing valuable insights into their architectural design.

EXPLORING VARIABILITY WITHIN 3D SHAPE COLLECTIONS OF FACADE PANELS OF MODERNIST MULTIFAMILY BUILDINGS IN NEW BELGRADE:
A METHODOLOGICAL FRAMEWORK

Djordje Djordjevic, Djordje Mitrovic, Mirjana Devetakovic

Modernist multifamily buildings in New Belgrade are renowned for their repetitive series of facade panels. Despite this apparent uniformity, significant variability in their appearance can be observed. Given that most of the buildings emphasised are over half a century old, the issue of their renovation, preservation, and maintenance is more acute than ever. Having certain 3D shape collections of facade panels, in a particular context, can significantly aid those processes. Nevertheless, as large repositories of 3D shape collections continuously grow, encoding the inter-cluster dissimilarity becomes important. This study aims to establish a methodological framework for exploring the variability within selected 3D shape collection of facade panels. The criterion for shrinking the study area to the Central Zone of New Belgrade (whose nine consisting blocks became cultural goods within a broader spatial cultural-historical entity in 2021) referred to whether some of the buildings considered simultaneously represent the cultural heritage. In our previous subject-related research, key morphological characteristics (in terms of varying) of facade panels of chosen building samples were identified, and several parameters (descriptors)

relevant to describing these characteristics were established. Fieldwork methods were encompassing in situ observation, recording, photographing, and noting an as-is panel appearance. To enable such appearance to be considerable in relation to the aim defined, the descriptive interpretation method (3D modelling) was implemented. The usage of morphospace (representation of possible morphologies, whose n-dimensional character depends on the number of traits being considered) is foreseen to systematically map and analyse varying of the panel morphology. To define such a space, here, each its axis should correspond to a different parameter from the set of inherited ones. Each point within thereby defined space would correspond to a particular combination of parameters, and thus, to a specific panel shape. A somewhat smaller number of parameters inherited can be declared adequate from the research-objective point of view (establishing methodological framework), despite the fact that the larger such number is, the more comprehensive morphospace structure will be. Comparing different shapes to each other and relating their traits to functional roles, morphological relationships could be studied. To identify potential diversity-wise patterns, the way different shapes occupy the morphospace, as well as the spread of points, could be analysed. Clustering algorithms would identify distinct groups of mutually (almost) identical facade panels. The results would highlight the subtle yet impactful differences in the panels' appearance that contribute to the architectural identity of the buildings they belong to. When it comes to research benefits regarding Shape Synthesis, both Shape Interpolation (blending between two or more existing shapes to create new intermediate ones) and Shape Grammar (procedural generation which ensures consistency in style whereas allows unique, site-specific adaptations) concepts would become applicable to panels. The goal of the research is to further develop a methodology implemented so as to become applicable to the study of other similar architectural heritage objects. This study points out the effectiveness of

establishing the methodological framework that combines shape reconstruction, feature extraction, morphospace defining, and computational clustering in exploring subject-related variability.

NEUROAESTHETIC MEASURES OF HIGH-RISE HOUSING FACADES

Audrey Xu, Immanuel Koh

Façade is the face of a building and the connection between inner and outer spaces. It gives a building its identity and image and influences how people respond to it physiologically and behaviourally. Architects spend significant effort in designing building facades, often producing various design iterations and options for discussions with clients. Design decisions on façade are often varied and subjective. The paper examines the design strategies used in high-density public housing facades in Singapore and propose an approach to understand their effects on visual preference through quantitative studies. Façade physical attributes in this study consist of height and length, silhouette, figure ground, windows and openings, façade elements, horizontal and vertical lines, façade volume, and 3D convex hull. From the measurement of these façade attributes, façade indices are derived which include number of vertices on building silhouette, number of lines of symmetry, length to height ratio, figure ground factor, transparency factor, façade element factor, horizontal interface density, vertical interface density, horizontal to vertical ratio, and convexity. The extraction of these ten visual indices in turn serves as the basis for the parametric generation of new façades in creating a synthetic dataset. To examine their visceral responses, subjects are asked to view different façade designs in a controlled environment while wearing biosensors. The findings are framed as a methodological contribution to the area of cognitive architecture and visual preference. Future work currently being undertaken l leverages the synthetic façade dataset in training a deep neural work for predicting the façade indices directly.

KAHN'S TWO HOUSES: FROM FORMAL ANALYSIS TO ANIMATED SYNTHESIS

Heather Ligler

In a 1955 essay in Perspecta, Louis Kahn presents his "Two Houses," each composed of clusters of square areas with the same 26-foot module. Kahn noted that the houses, though different in design, "grow out of the same order." The formal analysis of the houses has been taken on in Eisenman's Ten Canonical Buildings (2008), which lays the groundwork for the further interpretation of Kahn's Adler and DeVore house designs. This study engages that foundation to investigate how the houses can be reinterpreted algorithmically to synthesize, automate, and animate the production of new house designs. In doing so, the work engages the primary motivation that Kahn explains for the intent of the two houses to evaluate how the "order of construction" is created in the houses to "suggest an even greater variety or design in the interpretations of what space aspires to become and more versatility in expression of the ever present problems of levels, services, the sun, the wind, and the rain" (1955). To formally learn from the designs in this way, this research employs the shape grammar formalism and the equivalence given to analysis and synthesis in its constructions (Stiny 2006). The paper is constructed in five parts. In the first part, Kahn's Adler and DeVore houses are introduced along with some key insights from Eisenman's close reading. In the second part, the question of how computational formalisms establish compatible frameworks for analysis and synthesis is established and the methods of rule development and automation in Shape Machine (Economou et al, 2020) are outlined. In the third part, the two houses are reinterpreted in an implemented shape grammar that encodes the logic of the

shared order of the houses in shape rules to produce a series of variations that reflect on the potentials latent in the original designs. In the fourth part, the relationships between the rules of the two houses formalized in the grammar and other works in Kahn's corpus are comparatively discussed. In the fifth and final part, the project concludes with insights related to Kahn's work, the alignment of analysis and synthesis in shape grammars and their implementations, and future potentials inspired by the project.

Economou A, Hong K, Ligler H, and Park J. 2020. "Shape Machine: A Primer in Visual Composition", J.-H. Lee (ed.), A New Perspective of Cultural DNA, KAIST Research Series, Springer Nature Singapore Pte Ltd, 65-92. Eisenman, P. 2008. Ten Canonical Buildings. New York: Rizzoli.Kahn, L. 1955. Two Houses. Perspecta, 3, 60-61. Stiny, G. 2006. Shape: Talking About Seeing and Doing. Cambridge: MIT Press.

SESSION 11

December 6
17:00
Chair: Catarina Ruivo

***Bruno Gomes Marques**, Architect, PhD's in architecture and civil engineering, is a post-doc Researcher at LESE - Construct - FEUP - Faculty of Engineering of the University of Porto and Associate Professor at the Faculty of Architecture and Arts of the Lusiada University of Porto. He has a degree in Architecture from the Lusiada University of Porto in 1996, Master in Urban Environment Planning and Design from FAUP - Faculty of Architecture of the University of Porto in 2001, PhD in Architecture and Urban Planning from the University of Valladolid, Spain in 2010 and Doctorate in Engineering Civil by the Faculty of Engineering of the University of Porto in 2011. He coordinated the "ECO-SUSTAINED DEVELOPMENT IN AFRICA" group between 2011 and 2014 at the Center for African Studies of the University of Porto. From 2013 to 2019 he has been supported by a fellowship of FCT for post-doctoral research under the thematic area of Sustainable Architecture, in developing countries. He integrates several editorial committees of scientific journals and international congresses. He has academic and professional experience in the areas of building architecture and rehabilitation, building technologies and energy efficiency in buildings, mainly using passive and semi-passive systems using Domotic as a complement to human action in the management of these systems. Currently conducts research and teaching activities related to Sustainability, Urban Design and Bioclimatic Architecture, and construction using earth materials. its field of action and intervention ranges from the desert climate of Africa to the polar climate of Antarctica.*

Gonçalo Castro Henriques *is a Full-Time Professor at the Rio de Janeiro Federal University (FAU-UFRJ) and coordinator of Laboratory of Models and Digital Fabrication (LAMO-Prourb). He is a European Doctor (FAUTL, Lisbon 2013), Master (ESARQ-UIC, Barcelona 2004), Architect (ESAP, Porto 2000) and Erasmus student (TUE, Eindhoven 1998). Former Vice-President and member of the Iberoamerican Society of Digital Graphics (SIGraDi). Architect, Professor and Researcher interested in the integration of generative systems (analogue, algorithmic and responsive) with simulation and digital manufacture (CAAD-CAE-CAM and robotics). Develops polysemic network activity stimulating exchange between academia, research and industry. Designed, built and taught in different countries and institutions.*

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Tatiana Teixeira*, Architect, urbanist and computational designer. Holds a Master Degree in Architectural Design from The Bartlett Architecture School (UCL), in London, in which she concluded with a distinction and Silver prize, a Master Degree from Instituto Europeo di Design (IED-RJ) and a professional Degree from PUC-Rio, in Rio de Janeiro. She is currently Professor at Federal University Rio de Janeiro and Project Designer at X-Topia, a design-research practice that explores the intersection of architecture and urbanism with technology and the public, social and cultural realm. In X-Topia she has been working on a wide array of urban interventions and small-scale prototypes, recognized internationally including the*

project AÈRIO, for the 17th Architecture Venice Biennale in 2021.

***David Leite Viana** has a post-doc. in Urban Morphology/ Civil Engineering (FEUP), a PhD in Urban and Spatial Planning (IUU-Uva), a DEA in Modern City and Architecture (ETSA-Uva), and a Dipl. Arch. (ESAP). He is head of the Urban Planning Division at Matosinhos Municipality, a professor at UPT, coordinator of the research area in Urbanism at CIAUD-UPT, a PhD supervisor in the doctorate programme on Architecture for the Contemporary Metropolitan Territories (Iscte), and PNUM Scientific Council Vice-President. He is co-founder and co-chair of the International Symposium Formal Methods in Architecture (FMA Symposia), a member of the Sophia Journal scientific board (CEAU/AAI-FAUP), an editor of Scopio Magazine (CEAU/AAI-FAUP) and member of its scientific board, and editorial board member of the journal Revista de Morfologia Urbana (RMU).*

***João Quintão** has a Specialization Degree in Urban Planning and Urban Design of The Built Environment (FAUP/FEUP) and a Dipl. Arch (FAUP). He is head of the Spatial Planning Department at Matosinhos Municipality, and he has been a public servant since 1999 at Matosinhos Municipality. He was head of the Urban Planning Division at Matosinhos Municipality between 2009-20 and coordinator of Crato' Local Technical Service between 1996-98. He was the coordinator of the revision of Matosinhos' Master Plan, which was finished in 2019. He has experience in the elaboration and coordination of different urban planning instruments at different scales and legal frameworks.*

***Rui Fernandes** has a master's degree in Geography from the University of Porto, and he is a public servant at the Urban Planning Division at Matosinhos Municipality. He has experience in the development of urban planning instruments and urban policies supported by the Geographic Information System (GIS). He also has an interest in approaching urban planning with GIS complemented by the collection, management, and visualization of data.*

PARAMETRIC SOFTWARE AND THE ARCHITECTURAL DESIGN

Bruno Marques, Darlene Julio

With technological advancement reaching an impressive speed due to the use of computational resources, more and more parametric software has helped in the optimization and rationalization of decisions in the process of development of the architectural project and its execution. The use of this tool in the process that has as advantages the possibility of changing the design in any circumstance without having to modify all the constituent elements of the model and the exploration of different design alternatives that can be developed in parallel using the initial definition of the model, generate a quick and easy exploration of a large amount of alternative solutions in the creation of the project. Rhinoceros, Archicad and Revit, are software that develop projects under the parametric interface, with Rhinoceros being the most used performing parametric modeling through the Grasshopper 3D programming graphical interface that uses plugins such as LadyBug that performs precise environmental studies for the generation of the shape of the building. Simplifying the analysis process and automates the calculations, providing easy understanding of graphical visualizations in Grasshopper's 3D modeling interface, in addition, it allows users to work with energy and natural lighting software such as "EnergyPlus", "Radiance" and "Daysim". A building is then presented where a survey and a climatic and thermal characterization was made through the Rhinoceros software using the Grasshopper Plugin and its components generating 2D and 3D interactive graphs

for the understanding of the behavior of the building in relation to its environment and climatic factor. These software are innovative proposals offer a design methodology that adapts very well to e complex nature of environmental problems, effectively allowing the architect to make the best design choices.

IN-FORMATION:
SHAPING TOOLS, COMPOSITION RULES, VISUAL THINKING AND THE CREATIVE PROCESSES

Gonçalo Castro Henriques, Marcio Nisenbaum, Tatiana Teixeira

This article reports the experimental development of the discipline “Conception Form for Architecture - CFA” at XXX University. CFA is a foundation unit of the Architectural Degree and has a theoretical-practical nature. Due to this nature, it is urgent to incorporate joint physical-digital processes. This integration requires consciously identifying both processes limitations and potential to enable a physical-digital combined use. The authors re-think the CFA processes and methodology using as case study the design for a shelter in a park, based in a classical design exercise in American and European universities, the Nine Square-Matrix (Van Acker 2022). The original CFA exercise used only physical resources, but the pandemic demanded a digital alternative. The version reported in the article creatively incorporates physical-digital processes to develop a generative system using visual grammars. The introduction addresses the theoretical context of the CFA discipline, the physical and digital methodological processes, the use of visual thinking and generative systems. The CFA theoretical foundation relies on studies on Architectural Form, as classical proportion treaties (Vitruvius, Alberti, and Durand), modern treatises (Loos, Van Doesburg, and Corbusier), aesthetics theories and visual perception introduced by the Bauhaus. The foundations include the reference books “Design Thinking” (ROWE, 1986) and “Architecture: Form, Space and Order” (CHING, 2002). The discipline has a publication resuming the theoretical methods (BARKI et al., 2009). The CFA practical methodology has roots in the techniques,

processes and physical materials. Semper (2004) historically relates four building archetypes with materials: stone (stereotomy), wood (carpentry), brick (ceramics) and textile (weaving). Today, in addition to physical materiality there is digital (im)materiality and the boundary is blurred. Flusser (FLUSSER, 2007) addresses the process of form "formation", including in this formation both physical and digital processes. Digital allows designing processes using digital fabrication to design matter itself (PICON, 2004). Generative systems, whether physical or digital, work according to both the system properties and constraints. To implement a system is necessary to develop whole-part relationships and vice versa. This relational idea has echoes in Vitruvius and Alberti treatises, which established metric relationships between the construction and their parts. Alexander (1973) states that to have generative systems is necessary to create rules that generate the systems themselves. Gaudí or Frei Otto's physical form finding anticipated computational systems, exploring emergence through materials, rules and parameters. Digital systems can be unconscious (computer as a tool) or explicit (computer as a process), although explicit processes require digital literacy (OXMAN, 2006). Finally, the article describes the methodology used to develop a shelter design using a generative system with visual grammars. This system methodology comprises two phases, 2D composition (physical) and 3D transformation (Digital). Finally, we present results, debating the advantages and disadvantages of each process and their combination. Results show advantages of integrating physical-digital processes with visual grammars in a systemic process. The authors designate this process, in a wider sense, as computational design.

COMBINING SPACE SYNTAX AND KERNEL METHODS IN THE DELIMITATION OF THE MATOSINHOS URBAN PRESSURE ZONE

David Leite Viana, João Quintão, Rui Fernandes

Faced with the urgency of ensuring more available housing to address solutions to the increasingly urgent demand for housing, the Matosinhos City Council approved the delimitation of the Urban Pressure Zone (ZPU) to increase municipal property tax (IMI) in urban buildings or autonomous units that have been vacant for more than two years. To define the delimitation of the ZPU, an approach based on formal methods in urbanism was adopted, based on the collection, processing, and visualization of diverse data from multiple sources, which allowed us to obtain indicators that revealed how the territory pulses in terms of demand for rent support, housing requests, vacant apartments and those with low consumption records, among others. In this context, a methodology was developed in a geographic information systems environment, emphasizing Kernel (Kernel Density Estimator) analysis techniques. Additionally, to translate the relationships between spaces lacking housing and their configuration territorially, a set of analyses was developed using techniques derived from Space Syntax. The article will focus on combining methods derived from the Kernel and Space Syntax, demonstrating the correlation between the incidence and intensity of the housing problem in Matosinhos and its configurational characteristics.

The option for producing density maps was not based on the relationship between

indicators and territorial units. Still, rather on the creation of density maps in light of the Kernel estimate, that is, according to an interpolation and pattern analysis technique. A spatial array of points allows identifying the intensity with which a given variable manifests itself in space. Maps are therefore obtained that represent not only the incidence of the phenomenon but also its intensity. Based on the Kernel density maps of each of the selected indicators, scenarios were created in which each of these inputs was associated with different weights. Apart from the creation of scenarios, a configurational study of the municipality was carried out, based on the construction of the axial map of the municipality, with around twelve thousand axial lines. From axial and segment readings, syntactic measures were used as reference. The purpose of these analyses was related to the refinement of the municipality's syntactic qualities, the respective degree of intelligibility of the urban system, and other correlations between the identified centralities. These were superimposed and compared with the Kernel analyses carried out to make the urban pressure felt in the municipality evident.

The delimitation resulting from this process substantiated an area of incidence of worsening of the IMI coinciding with the most structuring centralities of the municipality of Matosinhos, removing discretion and arbitrariness from this same worsening, with a significant impact on the owners of dwellings and vacant land and dwellings with low consumption. of water and electricity, as the IMI value will be increased by up to twelve times in a few years.

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