

**5th International Symposium
Formal Methods in Architecture
Book of Abstracts**

Editors: Eloy, S.; Leite Viana, D.; Morais, F.; Vieira Vaz, J.

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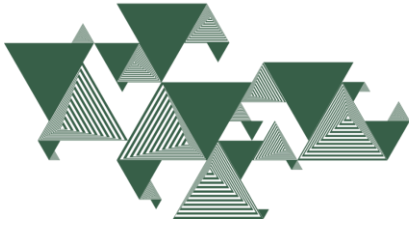
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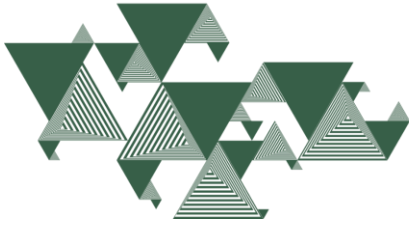
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Symposium Purpose

The main purpose of this symposium is a contribution to the debate in the fields of Architecture and Urbanism on the application of new formal methods to emerging societal and technical problems. Formal methods will be focused on methodological advances based on new developments coming from collaborative work with Mathematics and Computer Sciences which enables several different grades of abstraction and formalization. From the millennial geometry to current shape grammars, several formal approaches to Architecture and Urbanism are welcome to be presented. The aim of the symposium is to discuss, disseminate and promote the use of formal methods in the creation of new explicit languages for problem-solving in Architecture and Urbanism. We will discuss current problems in the field and the potentials and drawbacks of the use of formal methods to address them. These problems range from production, sustainability, representation, communication, heritage among others, never ceasing to see Architecture and Urbanism as technological activities and well as artistic ones.

Symposium Topics

Collection of information;
Semantic organization of information;
Syntactically and semantically formal languages;
Representation, visualization and interaction;
Architectural design automation;
Building performance analysis;
SCAVA-Space Configuration, Accessibility and Visibility Analysis;
Active management of the built environment.



Keynote Speakers

Reinhard Goethert | Principal Research Associate, Massachusetts Institute of Technology - Architecture, USA

Reinhard Goethert is internationally recognized in physical planning and upgrading of low-income settlements, in physical design and in participatory technique in urban development. He is Principal Research Associate in the School of Architecture and Planning at the MIT.

María Lopez Calleja | Associate - Architect, MVRDV, Netherlands.

María López Calleja studied architecture at the Technical University of Valencia and has worked for MVRDV since 2008. López is also responsible for the development and implementation of BIM as a design tool.

José Pinto Duarte | Stuckeman Chair in design Innovation, Director of the Stuckeman Center for Design Computing, Penn State College of Arts and Architecture, Stuckeman School, USA

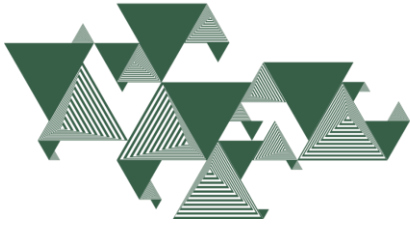
José Pinto Duarte is the Stuckeman Chair in Design Innovation and director of the Stuckeman Center for Design Computing (SCDC). He has served as president of eCAADe, helped establish the M.I.T.-Portugal program, and created the Design and Computation research group in Lisbon.

Tasos Varoudis | Senior Fellow, Leader and co-founder - Machine Learning Urbanism Research Cluster, Bartlett, UCL

Tasos Varoudis is a Senior Fellow at UCL and since 2011 he drives the spatial and architectural computation 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.

Ramzi Hassan | Associate Professor, NMUB – Norwegian University of Life Sciences, Norway

Ramzi Hassan is the founder and leader of the Virtual Reality Lab at NMUB. His research, teaching and publications focus on digital applications for landscape and urban design.



Abstracts



MATHEMATICALLY DEVELOPING BUILDING FACADES - AN ALGORITHMIC FRAMEWORK

Inês Caetano¹ and António Leitão¹

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The importance of Algorithmic Design (AD) is growing due to its advantages for the design practice: it empowers the creative process, facilitating design changes and the exploration of larger design spaces in viable time, and supports the search for better-performing solutions that satisfy environmental demands. Still, AD is a complex approach and requires specialized knowledge. To promote its use in architecture, we present a mathematics-based framework to support architects with the algorithmic development of designs by following a continuous workflow embracing the three main design stages: exploration, evaluation, and manufacturing. The proposed framework targets the design of buildings' facades due to their aesthetical and environmental relevance. In this paper, we explain the framework's structure and its mathematical implementation, and we describe the predefined algorithms, as well as their combination strategies. We focus on the framework's algorithms that generate different geometric patterns, exploring their potentialities to create and modify different facade designs. In the end, we evaluate the flexibility of the framework for generating, modifying, and optimizing different geometrical patterns in an architectural design context.

Keywords: Algorithmic Design, Mathematical Framework, Higher-order Functions, Facade Design.



BIM-BASED AIRPORT DESIGN PROJECT STANDARDIZATION (IFC) FOR USE OF CODE CHECKING

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Building Information Modeling (BIM) in the AECO industry is a fact. Users have overcome the initial learning curve and perceive a new potential for using BIM, such as rule checking and automatic design validation, which it's possible through dissemination and use of Industry Foundation Classes (IFC). This paper assesses the main properties that must be inserted in BIM models of airport design projects so that they can be evaluated using Code Checking. In this sense, the properties of the information standards will be analyzed and which IFC entities should be linked to those standards. The method is based on Design Science Research. This consists of two macro stages: Construction and Evaluation of the Artifact. The stage of Construction, discussed in this paper, consists of the theoretical foundation and construction of the artifact, which is a method to evaluate airport design using code checking. For evaluation, it is necessary not only to create consistent rules that can be implemented in BIM evaluation software. It is also necessary to create BIM models that are consistent during the assessment. This research shows the importance of creating a standardization process in the modeling of information during the development of airport designs in software authored by BIM, considering the export to an integrated IFC model. In view of the inexistence of manuals dealing with this subject in Brazil, it is possible to observe the potential that this approach has and may, shortly, benefit all teams of airport designs and analysts.

Keywords: Building Information Modeling; Airport; Code Checking; IFC.



L'OBJET INVALIDE

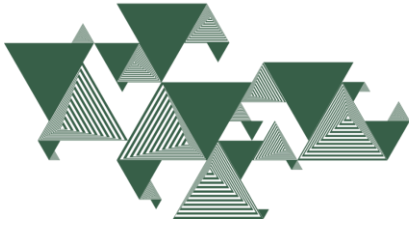
Aniruddha Mukherjee

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Over the course of this paper, I will consider categories of thought within architectural discourse from the poststructuralist paradigm as a primary resource. The texts and authors referred to are specifically those that discuss and critically analyse matters of authorship and origination among the arts and architecture. The poststructuralist paradigm offers a body of commentary on the primacy of written text over speech and its problematic with respect to appropriation and translation of form as well as content. A particular discrepancy to be disentangled in my research is the nature of the theoretical basis established by architectural authors of the period with respect to an anticipation of digital modes of design. The architectural projects during the period can be considered early statements that also attempt to establish the limits of tools available to architectural production, specifically where this concerns architectural representation. And, thus, can be read as having embedded within them a tendency for or maybe an exposition of those limits. The paper aspires to uncover and elaborate the modes of thinking and the consequent problems of translation, into an aesthetic, i.e. considerations of form and content or the lack of clarity on any such legible distinctions.

Keywords: Deconstruction; Meaning; Poststructuralism; (Re)origination; Form; Content; Conceptualization; Spolia; Validity



AGENT-BASED SEMIOLOGY: OPTIMIZING OFFICE OCCUPATION PATTERNS WITH AGENT-BASED SIMULATIONS

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Measuring the performativity of office space has been a long-standing topic of research. With the emergence of knowledge economy, the nature of work has changes considerably, foregrounding personal interaction and information interchange. Consequently, traditional tools of space evaluation, such as space syntax, have become increasingly difficult to apply. This research, therefore, uses a methodology based on agent-based simulation, focusing on agent behavior rather than on space morphology to assess the social performance of spaces. The research process is conducted in two phases: In a first research phase, simple social models are developed for the agent population in order to set up simulations that show differentiated agent behavior towards other agents and architectural frame dependency. A series of simplified yet plausible life-like office event scenarios with strategic changes to the furniture layout is used to evaluate and calibrate the simulation's social performance. Based on these simulations and the social algorithms derived from them, in a second research phase an experimental setup, that follows the generative logics of evolutionary design solving, is devised to identify office layouts with the highest social performativity. Methodically searching the design space for performance peaks, algorithmic design is used to generate, simulate, and test an initially large number of random scenarios against a set of predefined success criteria in order to obtain a subset of the most successful configurations.

Keywords: Agent-based semiology; Human space design; Work and office environments; Social performance simulation; Algorithmic design.



DIGITAL DOXIADIS: PARAMETRIC THINKING FOR HUMAN SETTLEMENTS

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This paper presents the output of 'Digital Doxiadis: Parametric thinking for Human Settlements', an architectural design workshop that took place in Chania on July 2015 with 25 participants. It was part of a two-year preliminary research project on the future of Doxiadis' unique European industrial settlement and based on the findings of two intensive workshops in Aspra Spitia and Athens on January 2015 and April 2015. One of its main goals was to bring Doxiadis' approach on the study and development of human settlements in the context of contemporary tools and associative parametric modeling. Custom design tools attempt to simulate the function and evolution of Aspra Spitia in Boeotia combined with industrial districts, assuming programmatic benefits through the application of selected Cluster Theory concepts, expressed as spatial rules. Reflecting on the experience and the workshop results we suggest that employing procedural parametric master planning offers the possibility of revisiting Doxiadis' pioneering analysis-based and data-driven anthropocentric ekistics, while the advantage of calculating directly output data for every design choice taken, augments the design process, shifting beyond the flexible urban configuration parametric model into an informed spatial exploration and quantitative decision making tool.

Keywords: Parametric modeling, Doxiadis, Ekistics.



TECTONICS OF DIFFERENTIAL GROWTH. FOLDS IN ADDITIVE FABRICATION AND MOULDING FOR ARCHITECTURAL DESIGN

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Differential growth is a process of volumetric expansion with spatially uneven intensity, which results in appearance of folds and is an infinite source of patterns in nature. Examples of differential growth are particularly prevalent in epithelial tissue. The paper proposes to use algorithms simulating differential growth for additive fabrication of moulding of architectural structures. The project starts with a research of folding at the level of epithelia cells and proposes a geometrical model simulating the process. Chosen geometrical approach has the advantage of continuity and closeness of any horizontal cross-section, which allows for rapid additive fabrication as well as for use as a mould. Since one of the main issues of additive fabrication at construction scale is the problem of keeping production time down while keeping the detail scale required for the finish, authors propose 3d-printing moulds with extremely thin walls. This moulds are later filled with liquid material after hardening of which the structural qualities are reached. Small thickness of the walls is essential for the production speed and its vulnerability to deformation is solved by simultaneous filling of the mould from both sides, with materials of similar density. The outer material is later extracted and recycled. Project results in production of several prototypes, which demonstrate the structural, spatial and aesthetical qualities of the approach. Project unravels and explores the potential of the surface maximization in relation to environmental impact of the architecture, in particular heat dissipation.

Keywords: Differential growth; Folds; Fabrication; Moulding

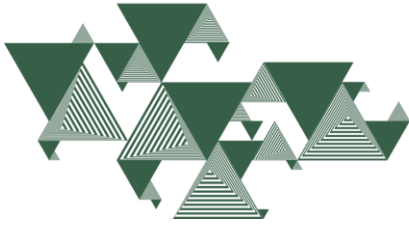


DESIGN TO EXPERIMENT - EXPERIMENT TO DESIGN: TOOL (USER, BREAKER, DESIGNER)

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This study aims to present a curriculum with three-fold experimental modules in the field of digital modelling and discuss the reflection of the module on students' learning and making processes. The paper proposes an experimental approach to addressing introduction of CAD/ CAM tools in design education, enhanced by constructivist theories of teaching. The submodules we call tool- (user, breaker, designer) allows students to make digital modelling by experiencing a variety of tools. We introduce the outcomes of the course and interrelations between submodules and students' engagement in students' learning process. Initial findings suggest that the students' personalization of the design tools in the tool breaker phase and associating them with their own experiences contribute positively to the development of a unique perspective in the design process.

Keywords: Design Process, Design Pedagogy, Learning by Doing, Experimental Methods, Constructivism.



WHAT ABOUT IF BUILDINGS RESPOND TO MY MOOD?

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This work analyses the possibilities of interaction between the built environment and its users, focused on the responsiveness of the first to the emotions of the latter. Transforming the built environment according to the mood, feelings, and emotions of users, moment by moment, is discussed and analyzed. The main goal of this research is to define a responsive model by which the built environment can respond in a personalized way to the users' emotions. For such, computational technical issues, building construction elements and users' interaction are identified and analyzed. Case studies where an occurs an interaction between the physical space and users are presented. We define a model for an architecture that is responsive to the user's emotions assuming the individual at one end and the space at the other. The interaction between both ends takes place according to intermediate steps: the collection of data, the recognition of emotion and the execution of the action that responds to the detected emotion. As this work focuses on an innovative and disruptive aspect of the built environment, the recognition of the new difficulties and related ethical issues are discussed.

Keywords: Responsive Architecture; Interaction; Users' Responses; User's Emotions; Ethics.



UPGRADING PARTICIPATION THROUGH COMPUTATIONAL THINKING IN ARCHITECTURE

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Advances in socio-technologies have contributed to a cultural shift towards active participation in society and eventually gave rise to a participatory culture. In the design context, the distinction between pseudo and genuine participation comes into prominence. This paper traces the intersection and convergence of design participation and design computation in architecture. The starting point of this research is an inquiry into the thread of user participation in architectural design grounded in the design methods movement as an alliance between participation and computation. For the purpose of studying relationships between participatory design and computational design, this paper revisits the premises of the 1971 Design Participation Conference together with early examples of architectural participation projects from the '70's (Lewisham Houses of Walter Segal, and Supports of John Habraken) and the computational realizations of these early participatory models (John Frazer's computational model of Segal Method, and MIT's Open Source Building Alliance's computational model of Supports). This exploration suggests that computational design thinking can be addressed to open and extend architectural design to a wider range of participants, upgrading the first participatory paradigm. The design of norm/objective/genotype by the architect and that of form/object/phenotype by the user is studied to support this argument.

Keywords: Design participation, Computational design, Norm vs form, Design research, Architectural Design



BOREALIS SOUND AN INTERACTIVE WALL FOR SITUATIONAL AWARENESS: THE IMPACT OF RESPONSIVE ARCHITECTURE ON USERS

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This paper refers to the presence of visual communication elements in public spaces using interactive multimedia surfaces. The state of the art, the development of a proposal and its evaluation is presented. The interactive surface applies to school of music “Escola de Música do Conservatório Nacional”, to which a design project was done in an academic context. The proposal aims to explore the incorporation of digital multimedia surfaces enhancing new dynamics while users walk in the interior of the building. Visual content will be displayed and the interaction between users and the multimedia surfaces is done by the sounds produce by people and instruments. To assess the intuitive nature and relevance of the proposal, satisfaction and usability tests were conducted with the potential users. It was concluded that users appreciated the proposal and were able to perceive the effect people’s presence have in the interaction with the multimedia surface.

Keywords: Responsive Architecture; Interaction; users’ responses; multimedia; interactive wall; sound; user’s testing.



TOOLS FOR THE CO-DESIGNING OF HOUSING TRANSFORMATIONS: A STUDY ON INTERACTION AND VISUALIZATION MODES

Sara Eloy¹, Micaela Raposo, Fábio Costa and Pieter E. Vermaas^{1,2}

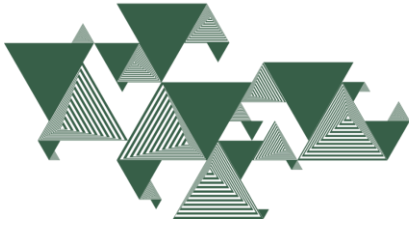
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In this paper we present and assess tools for visualizing architectonic modifications of existing housing in co-design projects with inhabitants. These tools should enable inhabitants to explore and understand design variations of alterations of their houses. This contribution is part of ongoing research on the use of artificial realities for supporting the transformations of existing housing in architectonically responsible ways. Such transformations may be needed after the delivery of housing, say after five years or later, due to changed regulation, the need of updates or changed living conditions of inhabitants. For arriving at architectonically responsible transformations we use shape grammar system for defining possible modifications of the housing. For empowering inhabitants to understand and explore these modifications to their housing we develop a transformation grammar tool – MyChanges – to visualize the modifications by three visualization modes, from fully-immersive to non-immersive. Interviews and tests with real inhabitants were performed and preliminary conclusions show that a tool like the MyChanges would have a good acceptance among inhabitants.

Keywords: Participatory Design, Generative Design Tool, Virtual Reality, Users' Feedback



BUILDING CIRCULATION FROM A SYNTACTIC CONTEXT IN RELATION TO INDOOR THERMAL ENVIRONMENT

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Building circulation layouts channel materials, energy, information, and people from one location to another inside a building and reflect the overall building spatial organization which is sought to affect indoor thermal conditions. This paper is a theoretical review that performs a cross-thinking of researches in the fields of building circulation design and indoor thermal conditions. The methodology consisted of three steps. First, the general theories in indoor circulation design are reviewed, and a syntactic analysis approach is chosen to understand the movement patterns. Second, the adaptive approach of naturally conditioned spaces along with its affecting factors is addressed as a primary evaluator of indoor thermal conditions. Third, previous studies of both fields are presented, to confirm the relation between the syntactic measures to social and economic measures, and the geometric measures to indoor environmental measures. Based on the discussed concepts in both fields, a new thinking approach is proposed, relating syntactic measures to indoor thermal measures. This approach offers an early indoor thermal feedback on primary design decisions of the building layout. Further experimental work with quantitative measures is needed to confirm this proposition.

Keywords: Building Circulation, Syntactic Approach, Indoor Thermal Environment, Space Syntax, Configuration Networks.



NATURE PLEATED SURFACES

Maria João de Oliveira¹ and Filipa Osório²

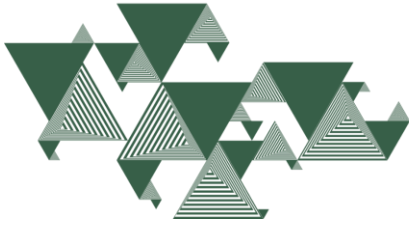
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This paper presents a concept design methodology that intends to enable users to design a self-supporting structure based on the terrestrial plants' biological properties and on origami geometric principles that was tested on an eight-hour workshop at eCAADe/SiGraDi'2019 in Oporto. Focusing on rigid and flat-foldable origami surfaces the methodology invites its users to deal with several architectural aims, constraints and analysis based on the geometric rules of this origami type. These surfaces behave in a particular way through folding, they depart from a planar state and after the folding process they arrive to a new planar state (flat-foldable Origami). If the faces remain rigid and flat during the folding process, the only change happens at the creases that behave as revolute joints. This way the folding of the surface is directly related to rigid kinematics allowing for a geometry based digital simulation. After the aims, constraints and analysis definition, the methodology users are conducted through an abstraction process that explores the three fundamental forms of nature adaptation strategies – morphology, behavior and physiology, giving rise to a hybrid biological principle that will lead to the conceptual design process. The design process is conducted through analysis, experimentation with paper prototypes and the use of parametric design, enabling this way the emulation of the design process, where the functionality, geometry, robustness and aesthetics are tested and discussed.

Keywords: Biomimetics; Rigid Origami; Methodology; Emulation; Parametric processes.



MULTI-SCALE CONFIGURATIONAL APPROACH TO THE DESIGN OF PUBLIC OPEN SPACES AFTER URBAN DISASTERS

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Housing shortage after urban disasters is often approached by governments and humanitarian organisations by building prefabricated houses that, during the transition between emergency and reconstruction, materialize the paradox of the permanency of a temporary situation. The events that followed the 2016-2017 seismic crisis in Central Italy do not seem to be an exception: in absence of permanent houses, the displaced people have been accommodated in S.A.E. (housing emergency solutions) within temporary villages of heterogeneous social, spatial and environmental qualities. With the aim to explore and improve way-finding in the disaster-impacted settlements as well as accessibility and sociability of the temporary sites' public open spaces, this paper proposes a human-centred design research approach in performance-based housing recovery planning and design decision-making, combining principles and methods from Space Syntax and Public Life Studies. This research demonstrates how to coordinate different digital analysis and design tools by illustrating their application in an urban regeneration project for Borgo1, a temporary housing settlement in the municipality of Arquata del Tronto. Specifically, the paper shows how a multi-scale and multidimensional study of the site allowed identifying the ideal location for a new public square and subsequently guided the design process towards the initial design goals' achievement.

Keywords: Temporary Housing, Disaster Recovery, Central Italy Earthquake, Space Syntax, Design Decision-Making.



SPACE, ADAPTABILITY AND USE - TRIANGULATING RESEARCH CRITERIA FOR ADAPTABILITY RETRIEVAL

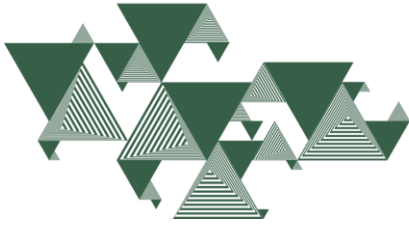
Carolina Coelho

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This paper presents a methodology to assess spatial adaptability by means of a broad range of criteria from intertwined research cultures, from a more analytical to a more cultural analysis of space use. In order to thoroughly assess all these stages of the building's lifecycle that impact on its adaptability, it focuses on several procedures undertaken for collecting data on this regard, but foremost, on the formal methods in architecture and spatial visualisation of the results. Thus, it proposes a multi-criteria methodology composed by three sequential milestones that describe specific building conditions on this behalf, towards a final retrieval of the building's adaptability. Milestone I describes the building's physical features and overall configuration, Milestone II describes all the possible activities it can allocate and Milestone III describes its effective appropriation. Finally, the retrieval of spatial adaptability is undertaken by a correlation of the most representative variables prior obtained in each stage. It is proposed that the three milestones enable the collection of a wide array of complementary data, whose representations also vary, but that overall provide a robust outlook on spatial adaptability.

Keywords: Spatial Adaptability, Use, Triangulated Research, Multi-criteria Analysis, Entropy.



DATA DRIVEN SPATIAL ANALYSIS OF URBAN RENEWAL. NETWORK KERNEL DENSITY ESTIMATION OF BUILDING RENOVATION

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Local and national governments are increasingly sharing openly large amounts of geo-referenced data related to city planning and administrative procedures. As such new opportunities arise for advanced data-oriented tools that are capable of providing insights on the spatio-temporal correlation of these phenomena. Kernel Density Estimation (KDE) appears to be an efficient tool for overcoming incomplete data, because not all urban rehabilitation needs to be reported to city hall services. Recently, new research has proposed Network Kernel Density Estimation (NKDE) as a more accurate alternative to estimate data in urban areas. This paper aims to provide a vision of the possibilities of integrating urban renewal dispersed datasets. We propose a method to measure the intensity of renovation in a network using the spatial database of building permits from the city of Lisbon.

Keywords: Building renovation, NKDE, urban renewal, spatial analysis.



PUBLIC SPACE USE: AN APPROACH TO LIVABILITY IN URMIA BAZAAR, IRAN

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The public liveliness based on how friendly an area is to walking reaches an important role for the Iranian culture, particularly when the social interaction take place in spaces like the 'Bazaar', or in the 'Mosque'. For the Iranian urban society, the 'Bazaar' is a place where the public space, works as a 'hub' where public life occurs as a result of social and cultural interaction. A new urban proposal developed by the municipality (2010) changed the Bazaar surroundings, building a large public space. The new square interacts with the ability to move around the central area of Urmia, it can affect the liveliness in the area, penalizing the pedestrian mobility. The study developed, on one hand, compares the soft mobility, based on proportion of urban pedestrian movement determined by the grid configuration itself 'natural movement' as Hillier et al (1993) as defined, which can be related with the syntactic measure 'integration' (Hillier & Hanson, 1984). On the other hand, the paper also studies, how the streets are to be passed through on all shortest routes from all spaces to all other spaces (Hillier et al, 1987), in the central area of Urmia, and within a predetermined distance, to analyze how the new public space increasing the public liveliness on the surroundings and within the covered space (Bazaar). The study allowed to conclude how the new urban structure can affect the pedestrian mobility through public space, and the changes made on the urban configuration can affect the public space liveliness.

Keywords: Bazaar, Public Space, Urban Form, Vitality, Urmia, Space Syntax.



NON-INTRUSIVE SEMI-AUTOMATED MODELLING OF ORDINARY BUILDINGS' INTERMEDIATE FLOORS: COLLECTIVE HOUSING IN PORTO, PORTUGAL

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Contemporary ordinary collective housing buildings constitute quantitatively the greater built heritage of many compact cities and in the near future they will need to be rehabilitated en masse. Their repetitive patterns promote the application of GIS/BIM modelling technology. Thus, this research develops a shape grammar to semi-automatically estimate the layout of the intermediate floors of residential buildings from their external shape. The grammar is based on the geometric capacity of floors to accommodate rooms in contact with the façade and to be divided into several dwellings. Grammar Part I (rooms) uses the topological concept of 'cells' to estimate the spaces behind the façades. Grammar Part II (dwellings and stairs) divides the floor into dwellings and locates the common staircase. This shape grammar is programmed in Arcpy (ArcGIS' Python library) with variations in accordance with its tools, restrictions, and processing performance. Finally, this shape grammar's script is applied to one hundred collective buildings in Porto, studied in a previous PhD thesis. The results of this sample illustrate that the shape grammar can estimate reality in many cases, revealing an underlying ordinary model with varying standards. Moreover, it offers a relevant analysis of the buildings' capacities and morpho-typological characteristics, even for irregular geometries. Its general applicability, non-intrusive methods, and enmasse processing can be useful in quantitative analyses and pre-liminary modelling for urban regeneration studies and policies.

Keywords: Ordinary buildings, Layout estimation Shape grammars, GIS processing in Arcpy, Python.



ADAPTING ANALYSIS WORKFLOWS TO HUMANITARIAN NEEDS: DIFFERENT ROAD NETWORK MODELS AND TOOLS

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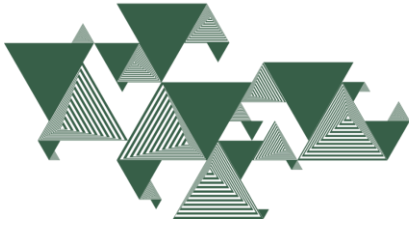
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Urban planners and decision-makers need to provide, with increasing frequency, a rapid response to the many natural hazards looming over cities today, while relying on limited information and computational resources. This research explores viable ways to support them in developing performance-driven proposals via urban modelling by: (i) exploring potential synergies between configurational analysis methods, open computing platforms and collaborative geo-data; (ii) testing the interchangeability of different road network models in a set of suitable case studies. Getting fast, free, and ubiquitous access to updated spatial information should allow decision-makers and experts to gauge relevant centrality and resilience properties of urban grids and bears opportunities for quantitative scenario testing beyond institutional boundaries. Therefore, this paper suggests linking knowledge and metrics from different street network analysis models and adapting analysis workflows to humanitarian needs to foster deliberation in strategic decision-making and tactical planning in urban disaster contexts. The results obtained in a set of suitable case studies indicate that, under certain conditions, time and computational resources can be saved, and interdisciplinarity boosted, by suitably interchanging primal and dual analysis models and tools. Nonetheless, further tests are needed to establish thresholds and generalize results.

Keywords: Street Network Analysis, Space Syntax, Volunteered Geographic Information, GIS, Python scripting.



URBAN FORMS OF INFORMALITY: DECOLONIALITY AS A PERSPECTIVE FOR MORPHOLOGICAL STUDIES

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Recent decolonial studies explore the possibilities for planning and urban investigation, promoting context-based research that acknowledge the distinctive and spontaneous practices of territorial occupation and questioning the universality of 'modernity' models. Considering the informal settlements as objects of study – constrained by poor conditions of living and, at the same time, characterized by collaboration and creativity – the paper addresses the lack of methodological tools for decolonial research and insufficiencies in morphological tools to tackle informality. It is discussed how urban morphology can operate in a decolonial framework drawing from previous research on classic and reconceptualized morphological principles. The possibilities for innovative paths and tools in urban planning practice using morphological knowledge from different schools of thought such as space syntax, process-typological and historico-geographical approaches (and their combination), are explored in the spatial and non-spatial features found in the autoconstructed scenario of different cities around the world. Traditional knowledge, cultural patterns and everyday practices are brought into discussion as important resources to enrich morphological analysis and informed planning practices.

Keywords: Urban Planning, Urban Morphology, Informality, Decoloniality.



UNDERSTANDING A BASTION CASTLE IN PIDHIRTSI USING THE SPACE PATTERNS SYSTEM FOR SPATIAL ANALYSIS

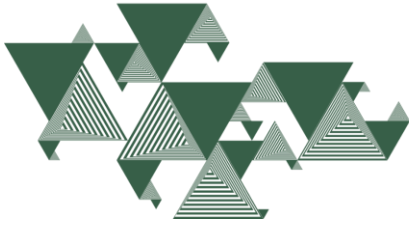
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In recent studies, scholars started to pay attention to space grammar and building organization more than to the building function, as the form and space of the building are more permanent than function. This paper expands the scope of an already used tool based on spatial analysis theory in residential buildings to more complex structures, such as bastion castles. This study aimed to investigate the use of the Space Patterns application to provide a comprehensive analysis of historic buildings regardless of their primary function. The method demonstrates the potential for the general applicability of this system to improve the understanding of building structure. It is a necessary step to a future adaptation of buildings to new functions, which became inevitable and urgent for bastion castles. The results showed that bastion castle in Pidhirtsi had well-lit spaces, 50–80% of the spaces have direct daylight access on each floor. The pedestrian circulation view captured the enfilade planning, characteristic feature for Renaissance villas.

Keywords: Bastion Castle, Spatial Analysis, Pidhirtsi.



RECONSTRUCTING PHOTOGRAMMETRIC 3D MODEL BY USING DEEP LEARNING

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In this paper, we propose a deep learning-based method to reconstruct 3D models generated with photogrammetry techniques. The mechanism to reconstruct the model is detecting corners and then segment the polyline contours based on the detected corners. Moreover, we take advantage of using a generative design tool (Grasshopper) to build a training gym system, constantly producing unique datasets to train the neural network. In the part of feature engineering, we use series of external angles as the geometrical feature to train the model; which means that the model processes a small number array instead of using images or any kind of huge multi-dimensional data. The result of this research reveals that the neural network model trained by our training gym system can learn how to detect corners on building contours successfully. The details of the training gym, dataset format, dataset generator, the deep learning model and the potential usages will be elaborated in the following content.

Keywords: Geometry Simplification, Deep Learning, Polyline Segmentation, Mesh Reconstruction, Photogrammetry



TOPOLOGIC: EXPLORING SPATIAL REASONING THROUGH GEOMETRY, TOPOLOGY, AND SEMANTICS

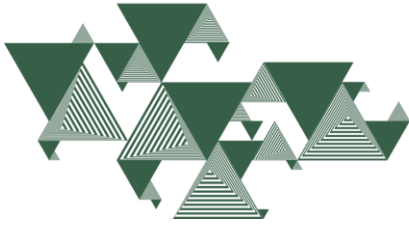
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This paper presents Topologic, a software modelling library that supports a comprehensive conceptual framework for the hierarchical spatial representation of buildings based on the data structures and concepts of non-manifold topology (NMT). Topologic supports conceptual design and spatial reasoning through the integration of geometry, topology, and semantics. This enables architects and designers to reflect on their design decisions before the complexities of building information modelling (BIM) set in. The paper summarizes related work on NMT starting in the late 1980s, describes Topologic's software architecture, methods, and classes and discusses how Topologic's features support conceptual design and spatial reasoning. The paper includes a report on a software usability workshop that was conducted to validate a software evaluation methodology and reports on the collected qualitative data. The paper concludes with reflection on Topologic's features and how it enables a shift from pursuing fidelity of design form to pursuing fidelity of design intent.

Keywords: Conceptual Design; Geometry; Semantics; Spatial Reasoning; Topology.



COLLABORATION OF VISUAL INTELLIGENCE BETWEEN HUMAN AND MACHINIC ACTORS IN DESIGN PROCESSES

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Design is a sensory practice; and for human actors inducing design processes, commonly vision is favored among sensory inputs. The reasons for this preference, are prospects provided by abstraction, diagrammatical thinking and sense-making through mental catalogues that in turn establish conceptual understandings of design organization – rules that represent conception of architectural forms – and representational structures where these rules are anticipated, created, updated, tested, simulated and maybe discarded. Following three decades of computational design research beginning with methodologies such as shape grammars, followed by CAD technologies emerging increased digital influence on the nature of design, today with advanced techniques such as incorporation of machinic intelligence in design tasks, visual intelligence in architectural design are provided with new potentials. The focus of design research in the scope of visual intelligence should be to locate different potentials in human and machinic actors to form the boundaries of responsibilities respectively aiming to form a collective visual intelligence propelled with the best of the both cognitive capacities. This facet is promising for achieving more complex and creative design orders and the paper scrutinizes different potentials in these two different cognitive capacities and argue for the advantages of each in the scope of computational design research.

Keywords: Visual intelligence, Conceptual and perceptual structures, Machine vision, Machine learning, Computational design



LBD SERVER: VISUALISING BUILDING GRAPHS IN WEB-BASED ENVIRONMENTS USING SEMANTIC GRAPHS AND GLTF-MODELS

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Over the last years, Building Information Modelling (BIM) has been increasingly adopted in building projects for its benefits to collaboration and associated risk mitigation. Recent work is trying to make this data available over the web (web-based BIM applications). Most notable in making building data web-ready is the Linked Building Data (LBD) initiative. This group has worked on a number of vocabularies and ontologies, thereby starting from a linked data approach (RDF graphs), aiming at representing building data on the web. Yet, a platform is needed that allows to manage the available linked building data, including 3D geometric visualisation, which is the topic of this article: a LBD server. The LBD server is a web-based application which allows users to upload building data and visualise their geometric representation in a graphical user interface, thereby also enabling to link to this data.

Keywords: Linked Building Data, IfcOWL, Web-based BIM, Xeogl



SCAVATOOLS: STRATEGIES AND TOOLS FOR THE MASS DISSEMINATION OF SCAVA TECHNIQUES

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This paper presents ScavaTools – a set of digital tools integrated into COTS software for architecture and urbanism (A&U). Its scope is on Spatial Configuration, Accessibility, and Visibility Analysis (SCAVA), correlating different methodologies and underlying theories such as 'isovists', 'space syntax', 'visibility graph analysis' and 'agent-based analysis' to A&U practitioners (with ease-of-use and facilitated access). ScavaTools overall aim is to overcome the user interface shortness of the current stand-alone software for this scientific area, in use within academic communities, but much less widespread in A&U professional activity. ScavaTools specific goals are i) to translate the usual CAD project to a SCAVA project, ii) the translation among themselves of the traditional five SCAVA models – (1) 3D and (2) 2D metric models, (3) segment and (4) axial line networks and (5) condensed spaces graphs, iii) to execute the necessary calculations to get SCAVA quantities (i.e.: visibility, distance, depth, control, skewness, accessibility, entropy, ...), and, finally, iv) to present to A&U practitioners a set of reports in a language easily readable by them. Those reports are functionally orientated, meaning solving A&U problems the A&U professionals asked ScavaTools to do. The paper describes the conceptual and discrete specifications of each of the five models and the eleven tools (which integrate ScavaTools software) developed to perform the four tasks described earlier (i-iv). Although the paper is a generic presentation of the conceptual structure of ScavaTools and not an operational handbook, it also presents some brief ideas of its operation.

Keywords: 3D Space Syntax, New Methods of Spatial Analysis; Formal Methods in Architecture



SPECTRAL CLUSTERING AND INTEGRATION: THE INNER DYNAMICS OF COMPUTATIONAL GEOMETRY AND SPATIAL MORPHOLOGY

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Deviating from common evaluation strategies of spatial networks that are realised through numerical comparison of single floating-point numbers such as global and local space syntax measures (centralities, connectivity, etc.) we aim to present a new computational methodology for creating detailed topo-geometric encodings of spaces that encapsulate some of the fundamental ideas about spatial morphology by Hillier [2007]. In most cases, space syntax measures try to capture a particular quality of the space for comparison but they lose much of the detail of the spatial topo-geometry and morphology by mainly aggregating graph path traversals and not retaining any other information. This research explores the use of weighted graph spectra, in a composite form, for the purpose of characterising the spatial structure as a whole. The new methodology focuses on the three primary space syntax graph modelling concepts, 'angular', 'metric' and 'topological', from the point of view of the resulting spatial geometries and develops new computational innovations in order to map spatial penetration of local neighbourhood spectra in different scales, dimensions and built environment densities in a continuous way. The result is a new composite vector of high dimensionality that can be easily measured against others for detailed comparison. The proposed methodology is then demonstrated with the complete road-network dataset of Great Britain. The main dataset together with subsets is then used in a series of unsupervised machine learning analyses, including clustering and a form of Euclidian 'spectral integration'.

Keywords: graph analysis, graph spectra, unsupervised clustering, space syntax, spectral integration.



SELF-LEARNING AGENTS FOR SPATIAL SYNTHESIS

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Over the last decades, a vast repertoire of computational methods has been employed for the synthesis of spatial configuration. Many of these techniques, such as the long-standing black box optimization or the recent generative adversarial networks, enable a quick exploration of the design solutions based on destructive operations, but encapsulate the generative process, inducing turn-taking between computer and designer. In contrast, techniques based on agents naturally provide partial design information and enable fine-grained interaction. However, existing agent-based models originate from non-architectural problems, so it is not straightforward to adapt them for spatial design. To address this gap, we present a method to create custom spatial agents that can satisfy architectural requirements. While the method can be adapted to a diversity of representations and goals, we focus on a proof of concept where agents control spatial partitions (represented as polyominoes with no holes) and interact in an environment represented as a grid. The agents learn how to satisfy its individual (shape, area, etc.) and collective goals (adjacency) using multi-agent deep reinforcement learning. In this paper, we focus on the formulation of the environment, agents, and goals, and present simulations of trained agents to illustrate possible variations.

Keywords: Space planning, Interactive generative systems, Multi-agent deep reinforcement learning



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