Architecture and Planning Journal (APJ)

Volume 28 Issue 3 *ASCAAD 2022 - Architecture in the Age of the Metaverse – Opportunities and Potentials*
ISSN: 2789-8547

Article 19

March 2023

A PIXELS-BASED DESIGN APPROACH FOR PARAMETRIC THINKING IN PATTERNING DYNAMIC FAÇADES

ZAKI MALLASI
Hickok Cole Architects,301 N Street, NE, Suite 300, Washington, DC 20002, USA, zaki@iconviz.com

A PIXELS-BASED DESIGN APPROACH FOR PARAMETRIC THINKING IN PATTERNING DYNAMIC FAÇADES

Abstract

In today's Architectural design process, there has been considerable advancements in design computation tools that empowers designer to explore and configure the building façades schemes. However, one could formally argue that some processes are prescribed, lacks automation and are only for the purpose of visualizing the aesthetic design concepts. As a result, these design concept explorations are driven manually to exhibit variations between schemes. To overcome such limitations, the development presented here describes a proactive approach to incorporate parametric design thinking process and Building Information Modeling (BIM). This paper reports on an ongoing development in computational design and its potential application in exploring an interactive façade pattern. The objective is to present the developed approach for exploring façade patterns that responds parametrically to design-performance attractors. Examples of these attractors are solar exposure, interior privacy importance, and aesthetics. It introduces a paradigm-shift in the development of design tools and theory of parameterization in architecture. This work utilizes programming script to manipulate the logic behind placement of faced panels. The placement and sizes for the building facade 3D parametric panels react to variety of Analytical Image Data (AID) as a source for the design-performance data (e.g.: solar exposure, interior privacy importance, and aesthetics). Accordingly, this research developed the PatternGen(c) add-on in Autodesk ® Revit that utilizes a merge (or an overlay) of AID images as a source to dynamically pattern the building façade and generate the façade panels arrangement rules panels on the building exterior. This work concludes by a project case study assessment, that the methodology of applying AID would be an effective dynamic approach to patterning façades. A case-study design project is presented to show the use of the AID pixel-gradient range from Red, Green and Blue as information source value. In light of the general objectives in this study, this work highlights how future designers may shift to a hybrid design process.

Keywords

Computational Design, Analytical Image Data, Image Pixels, Parametric Geometry, BIM, Building Façade, Patterning.

A PIXELS-BASED DESIGN APPROACH FOR PARAMETRIC THINKING IN PATTERNING DYNAMIC FAÇADES

ZAKI MALLASI

Hickok Cole Architects, 301 N Street, NE, Suite 300, Washington, DC 20002, USA
zaki@iconviz.com

ABSTRACT

In today's Architectural design process, there has been considerable advancements in design computation tools that empowers designer to explore and configure the building façades schemes. However, one could formally argue that some processes are prescribed, lacks automation and are only for the purpose of visualizing the aesthetic design concepts. As a result, these design concept explorations are driven manually to exhibit variations between schemes. To overcome such limitations, the development presented here describes a proactive approach to incorporate parametric design thinking process and Building Information Modeling (BIM). This paper reports on an ongoing development in computational design and its potential application in exploring an interactive façade pattern. The objective is to present the developed approach for exploring façade patterns that responds parametrically to design-performance attractors. Examples of these attractors are solar exposure, interior privacy importance, and aesthetics. It introduces a paradigm-shift in the development of design tools and theory of parameterization in architecture. This work utilizes programming script to manipulate the logic behind placement of faced panels. The placement and sizes for the building facade 3D parametric panels react to variety of Analytical Image Data (AID) as a source for the design-performance data (e.g.: solar exposure, interior privacy importance, and aesthetics). Accordingly, this research developed the PatternGen(c) add-on in Autodesk ® Revit that utilizes a merge (or an overlay) of AID images as a source to dynamically pattern the building façade and generate the façade panels arrangement rules panels on the building exterior. This work concludes by a project case study assessment, that the methodology of applying AID would be an effective dynamic approach to patterning façades. A case-study design project is presented to show the use of the AID pixel-gradient range from Red, Green and Blue as information source value. In light of the general objectives in this study, this work highlights how future designers may shift to a hybrid design process.

Keywords: Computational Design, Analytical Image Data, Image Pixels, Parametric Geometry, BIM, Building Façade, Patterning.

ملخص

هناك تطورات كبيرة في عملية التصميم المعماري باستخدام أدوات التصميم بالحاسوب التي تمكن المصمم من استكشاف مخططات واجهات المبنى وتكوينها. ومع ذلك ، يمكننا استدراج ان بعض التصميمات المستخرجة بأنها عمليات وصفية وقد تفتقر إلى التشغيل التلقائي وان بعض نتائجها فقط لغرض تصور مفاهيم التصميم الجمالي. نتيجة لذلك ، يتم توجيه استكشافات مفهوم التصميم هذه يدويًا لعرض الاختلافات بين التصميمات. للتغلب على هذه القيود، تصف ورقة البحث هنا طرحاً لدمج عملية التفكير التصميمي المعياري ونمذجة معلومات البناء (BIM). تقدم هذه الورقة تقريراً عن التطور المستمر في التصميم الحسابي وتطبيقه المحتمل في استكشاف انماط لواجهة المبنى ومن ناحية تفاعلية .الهدف هو تقديم النهج المطور لاستكشاف أنماط لواجهة المبنى التي تتفاعل بشكل ما وخاصية الأداء التصميمي. ومن الأمثلة على هذه العوامل التفاعلية هي التعرض لأشعة الشمس، أهمية الخصوصية الداخلية، والنتيجة الجمالية. تقدم هذه الورقة نقلة نوعية في تطوير أدوات التصميم ونظرية البارامترية في الهندسة المعمارية. يستخدم هذا العمل نص برمجي للمعالجة الكامنة وراء وضع الألواح في واجهات المبنى. يتفاعل موضع وأحجام الألواح البارامترية ثلاثية الأبعاد لواجهة المبنى مع مجموعة متنوعة من بيانات الصور التحليلية (AID) كمصدر لبيانات أداء التصميم (على سبيل المثال: التعرض للشمس وأهمية الخصوصية الداخلية والجماليات). وفقًا لذلك ، طور هذا البحث برنامج إضافي بمسمى PatternGen (c) في Autodesk ® Revit التي تستخدم دمجًا (أو تراكبًا) لصور AID كمصدر لتكوين نمط ديناميكي لواجهة المبنى وإنشاء لوحات قواعد ترتيب لوحات الواجهة على السطح الخارجي للمبنى . يختتم هذا العمل من خلال تقييم البرنامج وتطبيقاته على مشروع مختار ودراسة منهجية تطبيق AID ستكون نهجًا ديناميكيًا فعالاً لتزيين الواجهات. يتم تقديم المشروع مختار تصميم كحالة تصميم دراسي لإظهار استخدام نطاق تدرج البكسل AID من الأحمر والأخضر والأزرق كقيمة لمصدر المعلومات. في ضوء الأهداف العامة لهذه الدراسة ، يسلط هذا العمل الضوء على كيفية تحول المصممين المستقبليين إلى عملية التصميم المختلط متوازن.

الكلمات المفتاحية: التصميم بالحاسوب، بيانات الصورة التحليلية ، بكسلات الصورة ، الهندسة البارامترية ، BIM ، واجهة المبنى ، الأنماط الزخرفية.

1. INTRODUCTION

1.1 Design Cycle: Analyses + Synthesize + Evaluate

Designers consider the paneling of facades as a significant exterior building feature to achieve the desired design goals and aesthetics. Typically, they depend on their design thinking skills (aesthetic, visual and function) for example, but with some constrained criteria to inform the design (Rorig, et. al, 2014). At present, architectural firms and many academic architectural programs are indeed embracing parametric modelling into the early design stages to produce different design representation. As illustrated in figure 1, this changes the mindset of designers because it requires embedding certain logic in relation with façade penalization geometry and the output (Turrin, et. al, 2012). As far as façade paneling is the goal here, the articulation considers the geometry of the façade such as: pattern, form, boundary, panel size and types of panels to represent the intended design function. Consequently, this work is motivated about how to explore a proposed approach for combining parametric thinking and Analytical Image Data (AID) images as a creative method to assist in understanding of the fundamental issues that strengthen the theory to produce and express complex façade architecture.

Park et. al. (2004) believes that computational design can address the proposition that architectural design is transitioning to an analytical process of inter-connected factors, and it makes it a new phenomenon. From an industrial product design and development perspective, one may consider the building as a product. In fact, a LEAN thinking method used in other engineering fields can be applied in architecture to encourage the analysis + synthesizes + evaluate design cycle when paneling building facades. Some precedent examples are from structural and mechanical engineering fields dealing with visualizing design and performance for the design of structural elements based on stress/load color visual analysis. The case is different in Architecture where there were long overwhelmed due to cost and complexity in design practices (Luebkeman and Shea, 2005). Along these lines, what is essential to this work is crossing over any barrier among research and practice to grow the ability to expand expertise in the patterning of dynamic facades being executed based on parametric modelling.

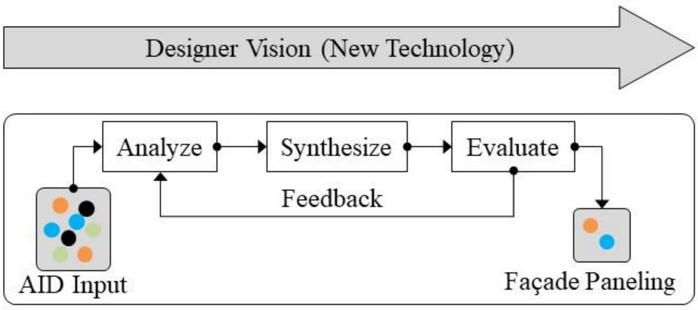

Fig.1: Mindset Diagram and Color-Base Analysis Example

1.2 Architectural Sketching and Parametric Design Language

Architectural design sketching is fundamental to the creative idea production process, and it resembles a focal effort for emerging design ideas that is stimulated by the designer’s creative imagination. It is a process that is dynamically relying on interacting with illustrations as design language. McFadzean (2000) described that hand-drawn sketching are a significant piece of the entire design process and that it engages the use of past experiences or thoughts. This work reports that this sketching procedure can be seen as a trigger instrument for recalling design moments or style. This is a 'marks retrieving' action and can be identified with the designer's style and potentially distinguishes key factors in design direction. In this regard, the proposition in this paper recognizes that parametric design can be seen as visual design language to permit designers to think with shapes and forms as marks to be part of the conceptual design process.

DOI: 10.54729/2789-8547.1214

	
Hill County Sez Office Complex by SOM (Source: Mark Igou, https://src.lafargeholcim-foundation.org/)	*Thematic Pavilion by SOMA (Source: https://www.designboom.com/)*

Fig.2: Examples of Architecture of new avant-garde

The capacity to utilize complex rules for shape configuration are linked with the ability to initiate a ‘creative triggers and to engage inventiveness (Barrionuevo et. al. 2004). The mechanism for triggering creativity inspires the design process and can be anything: an object, geometrical combinations, spatial relationship, aesthetic, etc. Scholars like Lionel March suggested that shape configuration rules and computational design mechanism prompts surprise and serendipity (Earl, 2000). A key thought in this work is to present parametric modelling as an approach to formulate a language for modern façade emergence, especially as seen in the new avant-garde that emerged within the span of the last ten years (figure 2). Reputable architectural firms are known of demonstrating the merits from utilizing parametric expression. One can see a shift from the conventional surfaces to tectonic surfaces and developed exterior envelopes that we call now the post-digital age. For example, this process is notable in the example projects shown in figure 2 whereby dynamic façade is represented by different aspects: surfaces type, repetition, panel geometry (shape and size), pattern configuration, material, and design concept. John Frazer (1995) described the metaphor for such imaginative shape configuration process as:

> *“Using the computer - like genii in the bottle – to compress evolutionary space and time so that complexity and emergent architectural forms are able to develop. The computer of our imagination is also a source of inspiration – an electronic muse”.*

1.3 Parametric Utility and Design Transformation

Every designer uses a variety of methods to work out the relationships between the elements of the architectural facade. This may involve several design modifications such as: adjustments, refinements, structuring, and representation in a way to visualise and conveys the works (Harfmann, 2012). However, the manual editing of object-to-object relationships in most CAD systems to alter the geometry clearly is isolated from design-automation as well as being subjective to the designer’s implementation.

Nowadays, parametric modelling is embedded inside Building Information Modelling (BIM) as a master model comprising parts and sub-parts within the BIM model (Park and Holt, 2010). The BIM model contains the parametric values for every 3D object and its relationship to other objects and is adaptive to the continuous design state. The core concept in parametric modelling is that objects and sub-items are related to each other through parametric rules and as a connected framework (figure 3). Any modification to one object would affect the current design state which has far reaching effects on the way designers reaches a design scheme.

In recent years, connectivity between parametric modelling tools and integration with external platforms have matured and made data-flow possible between data source and parametric objects. Parametric modelling platforms like Autodesk ® Revit, Rhino ® Grasshopper, CATIA®, Bentley ® Generative Components are available tools for designers to implement such data flow integration. Hence, such collaboration tools require a well-structured computational design workflow as it becomes more and more in the hands of the designers (Aish and Woodbury 2005). To this, the utilization of different source data stored in Excel or CSV text files can assist designers to alter the shape/size of the parametric façade panels. This paper focuses on the interactive rules between the designer and the parametric utility as channel for creativity and means for representing design ideas. This work utilizes Autodesk ® Revit BIM tool and the embedded Application Programming Interface (API) scripting. It developed an add-on with rules to change the properties of the 3D façade parametric objects. The add-on utilizes an Analytical Image Data (AID) as a data source input to configure the building façade panels. The goal is to allow designers to interact with facade patterning using parametric-driven design process and to enrich their creativity thru viable performance data. The proposition here is from a practical view and is implemented in an architectural project.

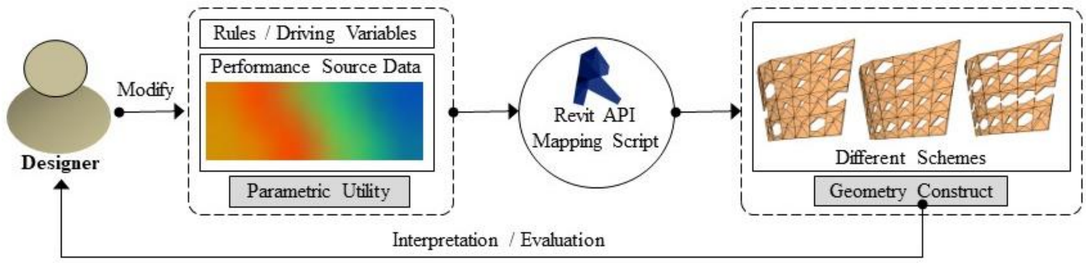

Fig.3: Parametric utility framework with designer interpretation loop.

1.4 Research Motivation and Objective

Even though dynamic façade patterning design feature is spreading, most designers depend on other specialized users with their parametric scripting skills. These tools deploy scripting environment such as: Maya Embedded Language (MEL), Revit API, Dynamo, C# programming language, Rhino Grasshopper, Visual Basic in Bentley Generative Components, etc. Even though the tools offer great degree of creativity and generative design exploration, they are expensive methods relating to intense scripted programming. These scripted programming are relatively new to architectural community and are based on mathematical code, coded instructions, formulas, creating macros, etc.

Consequently, the motivation in this work was to develop a computational design add-on as well as an approach to dynamically control façade panels. A relevant motivation also comes from the need for a hybrid design process is inherently parametric, it is important that designers use a tool with "simple" user interface. Not only this, but the hybrid design style could also maintain its promise for innovative advances in design articulation and how it is conceived. The goal of AID design approach is to illustrate the technical evolution from utilizing the dynamic patterning of the building facade and as an exploration tool in the early design phases. This work offers designers an understanding of the fundamental process that drives the building facade patterning while attaining to an approach for facilitating the early-stage design process.

This paper focuses on exploring the application of AID overlay images with main goals such as:

- To provide a generic tool for facade-patterning and design exploration.
- To demonstrate a simplified method for managing a complex parametric model and facade components where scripted program captures processes for the inherent performative logic.
- To automate the modification of façade panels in response to AID images.
- To report on new levels of complexity that might create unexpected aesthetic from the emerging design output.
- To define the computational workflow and process in support for architectural practice and academia especially when it comes to implementing computational design technologies.

2. METHODOLOGY FOR DESIGNING WITH COMPUTATION LOGIC

This section elaborates on the methodology for creating an AID driven facade configuration to understand relationships between AID image overlay and facade panelization design process. The methodology includes these three major phases described below to achieve the dynamic façade patterning.

2.1 Phase (1) - Tiling and Patterning the Façades

The beginning phase is the construction of a surface mesh geometry that has "U-direction" and "V-direction" 2D divisions (figure 4). These divisions resemble the initial 2D grid layout for receiving and organizing the panellized façade components. The figure 4 below shows an illustration of a wall prototype with sample rectangular 3D brick component. The initial wall surface and form presented in figure 4 below was created using the "Divided Surface" feature available in the Autodesk ® Revit massing environment. The Revit 3D conceptual massing environment is mainly used to apply the "UV" divisions (i.e. rectangular pattern) necessary to the façade panels. The designer can control the size (for example 10 X 15) and position of the "UV" 2D layout to describe the initial layout of the façade design. In this study we focus the development on the UV-grid limited to the rectangular patterned surfaces. As illustrated in figure 4, it is a laborious process to even alter manually a generic parameter "X" of a length type.

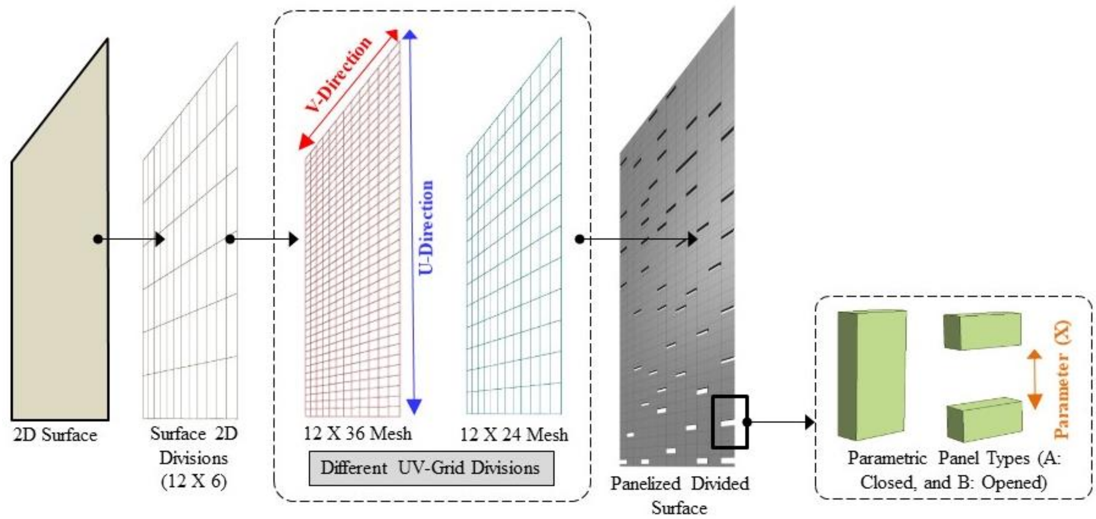

Fig.4: Revit Divided Surface UV-Grid Layout and Tiling (Phase 1)

2.2 Phase (2) - Image Pixels: Data, Values, Coding and Mapping

For simplification purposes, one may consider the building façade as a basic layout made of X and Y grid system connected like the one shown on figure 5 below. The façade panels responsiveness is driven by the different AID sources from a variety of performance sources like panel placement by program, solar exposure, visual aesthetics, etc. (Madeddu, 2011). For example, tools like Autodesk Revit Insight ® solar analysis plug-in, and design sketches in PhotoShop ® can produce AID bitmap image. In the same manner, each AID bitmap image has an X and Y grid made of pixels (e.g. 10X10) and each pixel Red Green Blue (RGB) values can be obtained and mapped on the facade X and Y grid system (i.e. Revit Divided Surface panels). As illustrated in figure 5 below, phase 2 in this work implemented C# programming language available in the Revit API to handles the data-values RGB value of pixels to the façade panel mapping.

As explained earlier, we are focusing on exploring the overlay of AID data sources as driver for façade panelization. We utilize a generic façade example as shown in figure 5 below to illustrate how a facade panel "X" parameter reacts to an overlay of three AID and produces a dynamic facade pattern. The designer will utilize this image-to-facade mapping approach and produces completely different variance of styles. The C# routines used would retrieve the input values of the AID pixels and convert them as greyscale values also known as ranging from White to Black with any shades of grey in between. In the context of manipulating the facade component parametrically, it is possible to manipulate the "X" dimension parameter based on the greyscale gradient image pixel values. The designer can assign any given criteria for "X" parameter to act as a manipulation mechanism for the facade panel properties such as: size, offset, depth, length, width, angular twist, etc. Therefore, informed decisions when exploring dynamic façade patterning is achieved thru the computational logic with using AID images.

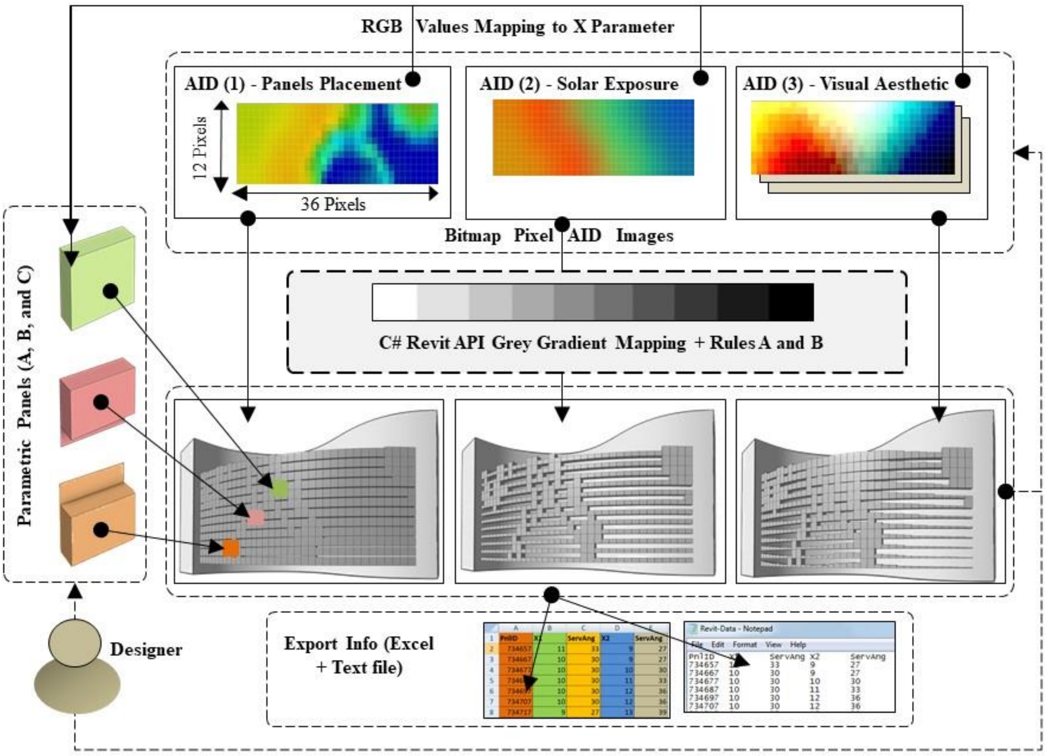

Fig.5: Facade manipulation phases and dynamic computation logic (Phase 2 and 3)

2.3 Phase (3) – Parametric Patterning

In this phase, the AID paneling approach mentioned above extends the possibility of varying the patterning rules for the building facade. This approach allows the encoding of façade patterns rules according to set of "Xn" parameters which are embedded inside the facade parametric panel. The objective is to assist the designer to explore a range of façade modifications using a generic parameter inside the parametric panel object. Here, the proposed patterning rules are the connecting relationship between the 2D AID bitmap pixel values which changes the value of the parameters "Xn". This is a semi-automated mechanism to alter the values of the "Xn" to see the patterning result on the façade. This work implemented the two rules (A) and (B) as described below, in Revit ® API C# routines to extract the difference in the greyscale colours of each pixel values to controls the "Xn" parametric values (see figure 5).

Rule (A) – Panel Type Selection and Placement:

In many situations, designers utilize aspects like practicality, aesthetic, visual privacy for the positioning of various facade panels. The iterations and management between these three aspects play a vital role in the parametric thinking process. (Hudson, 2009). For example, three different types of façade panels can be used: solid panel, panel with top opening and panel with bottom opening. For panel placement rule "A", solid panel types can be placed on the façade location where there is service/storage space behind it. In addition, the designer can choose to place a panel type with bottom opening if the interior space is public space (e.g. living room). The panel type and selection control mechanism are also driven from the greyscale percentage values in the AID image. Greyscale value corresponds with the panel type to be used. The figure 5 below shows how individual pixels with greyscale values from AID (1) can be coordinated to control placement of the panels.

Rule (B) – Xn Parameter Value Change:

The logic in this rule is very important because it controls the value of a specific “Xn” parameter. We limited the implementation of “Xn” generic parameters in this work to be applied as “X1” and “X2” for dimension “Length” type Revit parameters and “X3” of “Angular” degrees type parameters. Initiating this rule will extract the greyscale value for the specific pixel from the AID image. Then the greyscale intensity of a pixel is expressed in percentages within a given range between (0%) for white color and (100%) for solid black. The use-case listed below shall explain how this works when the user assigns “X1 =1 meter” as maximum value:

- If the greyscale of a pixel is 100%, then “X1” value remains as it is.
- If the greyscale value is (0%) then “X1” value becomes “0”.
- When the greyscale value is (50%) then “X1” value becomes “0.5 meter”.
- And so on it can be applied similarly for the parametric values of “X2” and “X3”.

Rules A and B are integrated in this work to help automating and updating façade schemes as the layout evolve from one scenario to another. This is a generic approach that serves the ideal world of designers and engineer to interact with a parametric thinking process by simply updating the AID images and overcomes the manual method of updating and re-drawing dynamic building facade in a BIM environment.

3. THE PATTERNGEN(C) ADD-ON DEVELOPMENT

The main development environment for the PatternGen(c) add-on in this work is the C# programming language and .NET Visual Studio. The C# routines uses the open Revit ® API features to manipulate panels in the façade geometry and the AID image mapping data transfer. A real-time data exchange is facilitated between the AID overlay of images thru the PatternGen(c) user interface as shown in figure 6 below. This in turn provides designers to alter the façade panel configuration dynamically and visualize their design concepts thru the Conceptual Mass modelling in Revit ®. The goals is essential to assist the design team to quickly view design options and make some basic informed decisions. Nowadays, the designers can generate different AID bitmap images from analysis tools like Daysim®, Revit ® Solar Radiation Add-on and Revit ® Insight. The background and conclusions form the literature observation in this work indeed anticipates assisting most designers by reducing the time, tedious process and special coding to modify facade components parametrically. As a result, the different parts for the PatternGen(c) add-on user interface are developed for simple input use like: loading an AID image, and applying the patterning rules mentioned previously. With this in mind, the user interface parts were necessary to allow the automated patterning and tiling of the facade panel components.

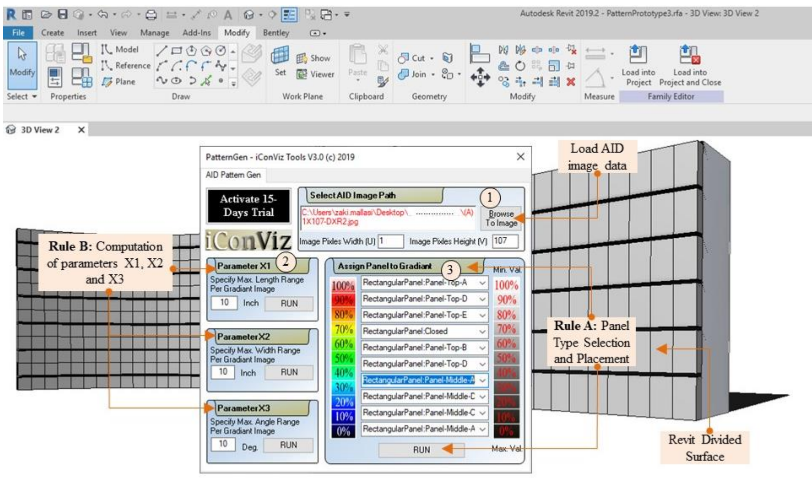

Fig.6: The PatternGen(c) main user interface parts developed by the author.

3.1 Patterngen(C) User Interface Parts and Controls

The PatternGen(c) development as add-on to the existing Revit® parametric environment provides several benefits from a developer point of view and to the end user. As shown in figure 6-1 previously, the PatternGen(c) user interface comprises a window application floating on top of Revit® that has access to the Revit® API functionality. In fact, this user interface has been developed from multiple feedback from users and several features were added which are more accessible to the user. As shown in figure 6 above, the add-on three parts facilitate the following controls and execution of rules A and B:

- **Part One:** allows the designer to select the AID image to be utilized in the façade panelling and as the datat source for the desired pattern. This is the first crucial step because when the AID image is loaded, the tool retrieves the pixel data for mapping on the "Divided Surface" Revit geometry. Not only that, but the add-on also displays confirmation that the AID pixel size and orientation is similar to the "Divided Surface" UV grid 2D layout. For example, an image of Pixel Size Width (10) by Height (20) is mapped on a "Divided Surface" of U=10 by V=20.
- **Part Two:** manipulates the change of values for "X1", "X2" and "X3" parameters based on applying Rule "B". As mentioned before, these values represent the greyscale of the AID pixilation mapped on the parametric panel values.
- **Part Three:** lets the designer to apply Rule "A" after loading the AIM image to begin panel type selection and placement per the greyscale AID pixilation range. In this regard, the panel types and placement choices are driven from the design function or the aesthetic requirements. As shown in figure 6, while the panel types of assignment is done manually by the designer, they are however placed in an automated fashion per the AID greyscale range. Then the add-on will compute the placement of the panel type on the "Divided Surface" according to the AID pixels.

3.2 Steps for Patterning A Façade

We define in the following the workflow for dynamically patterning a façade depending on the two main AID images: aesthetic and solar exposure. The flowchart shown in figure 7 below demonstrates such process taking into considerations three important steps to accomplish a practical workflow for a typical facade dynamic patterning.

The First Step makes usage all the functionalities of the parametric geometry and facade envelope that are modelled within the Revit ® Conceptual Design Framework. Here the designer models the 2D geometrical surface for the facade and subdivides it into UV tiles such as U=6 by V=30. The designer will produce the solar exposure AID image using the built-in Revit ® "Solar Radiation" functionality. Some of the benefits from using Revit ® Conceptual Design Environment is the ease of its 3D geometric modelling environment and the ability to obtain facade solar exposure internally without having to perform the analysis on external analysis tools.

In the Second Step, the user models the Revit ® Curtain Panel object which contains "Xn" parameters. In this way, each panel object would contain three panel types such as: A, B and C where each of the types has implemented "X1" and "X2" parameters to control the panel depth and/or opening size. The designer ultimately makes the decision to apply the AID driven computational logic either on "X1" or "X1". These parameters were intentionally named in such generic naming convention for easy of application and to abstract the parameters naming. In other words, another user for example may utilize "X1" for controlling the thickness or length sizes of a Revit ® Curtain Panel component.

The Third Step requires the user to hit any of the "Run" buttons to begin executing the patterning mechanism. This will initiate the dynamic patterning routines by applying the previously describes rules (A) or (B). Then, the values for the "X1", "X2" and "X" parameters is adjusted depending on the pixel/greyscale values obtained from the AID. The facade panel objects would reconfigure to execute the patterning results based on the computed/mapped greyscale. Furthermore, the designer can explore additional façade studies when applying different aesthetic AID images. The iterative process for this workflow can be seen as an abstract conceptual façade sketch where the designer can edit the AID image pixels areas to reflect and control panels on the façade. This was used to produce a facade model that is aesthetically evaluated part of the design process.

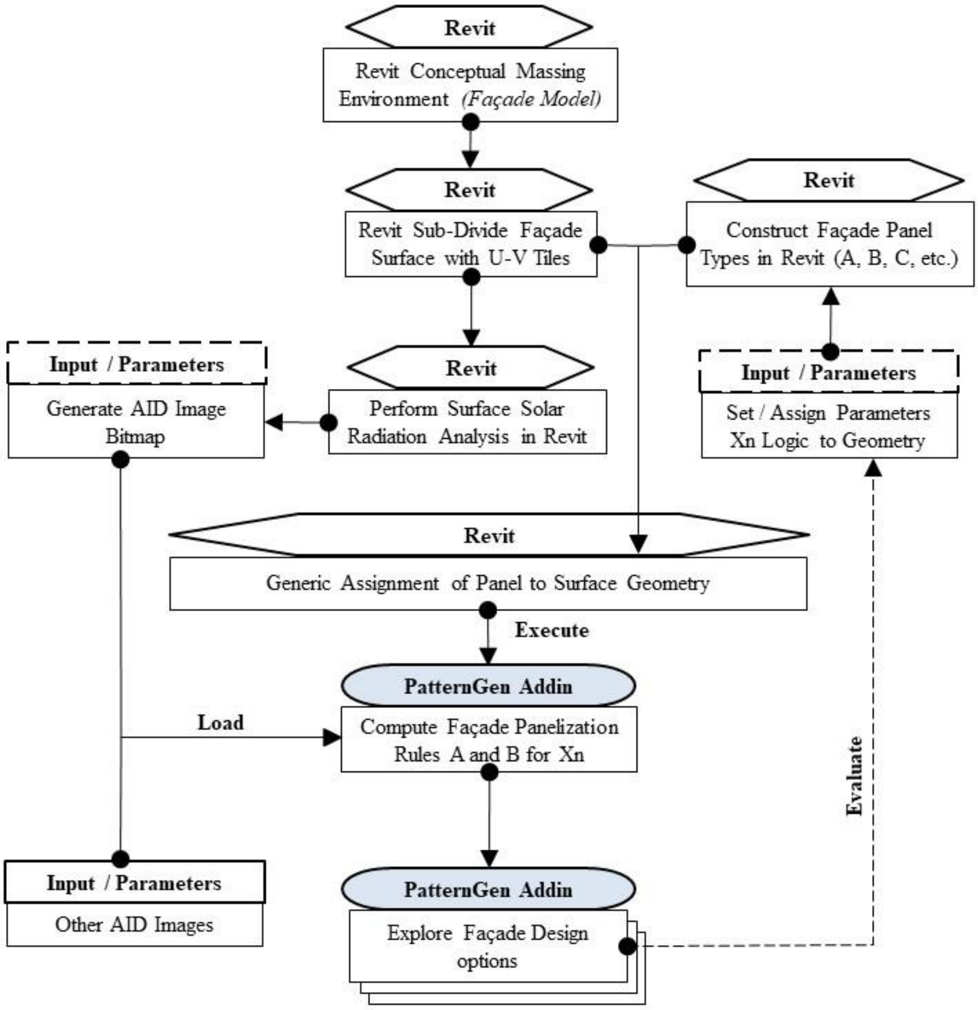

Fig.7: Proposed Computational Design Workflow Using the Add-on.

4. APPLICATION ON A REAL PROJECT DESIGN SCHEME

Computational design is a problem-solving and a dynamic process that demands the coordination between different goals. There are environmental, functional, aesthetics, and visual privacy to be considered before the production of an architectural artefact. Primarily, the focus when applying our proposed computational design approach in this work is to create architectural design output which recognizes the above coordination items. In addition, it is crucial for a complex design transformation to be created in BIM to leverage the integration of such process into future architectural design practice.

A real architectural project involved a design task for exterior façade of a small VIP Airport Terminal building constituting of four floors a total floor area of 6,800m2. The building is dedicated to being a world-class space to service passengers such as: check-in counters, arrival lounges, departure gates, duty free zones, food services areas, and supporting services. The project building exterior envelope comprised numerous challenges in terms of sun screening, views enhancement and façade function. The project is forming part of the overall airport client's newly constructed projects to enhance the passenger experience, create a facility that is modern and well-functioning.

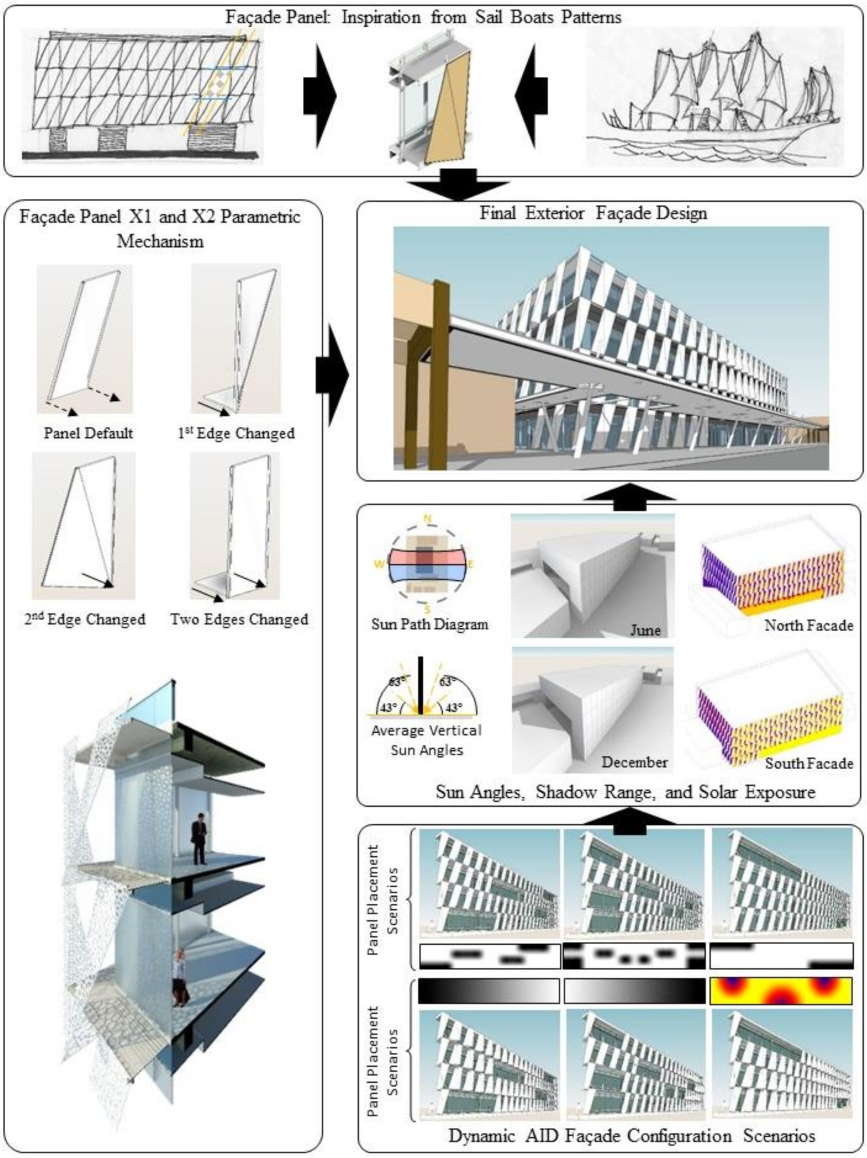

Fig.8: The case study project: facade boundary outline, parametric panel mechanism, and Boat sail pattern inspiration.

The general building envelope concept is illustrated in figure 8 below and is driven by several aspects. They are mainly an inspirational response to the interlaced grid pattern which mimics Yachts sails surface areas and responds to the hot climate. The formed exterior panels are emphasized from the effect of patterned panels that dynamically gives an effect of an overlapping sails. The façade will have a visible contemporary presence as well as appreciating the traditional local culture. Among several design schemes presented to the client were focusing on articulating the building envelope to read as contemporary and in harmony with the surrounding sea-life/boats traditional local culture. The author, as being the Lead Designer on the project, embraced the opportunity to experiment with the AID performance-based design approach on this project. Most of these schemes presented here formed a prototype for experimenting with parametric thinking for Configuring and Designing Dynamic Building Façade. The exterior façade is climate-aware in terms of utilizing a simple exterior façade panel made of perforated panels to reduce overall exterior solar exposure while maximizing view from inside to the outside.

4.1 Pixels Mapping Scenario on the Façade Panelization

In this project, the placement of the panels on the exterior façade is of a static nature and plays a major role as a shading system inspired by the overlapping of the Boat latticework (figure 8 – shows only panel mechanism). Since the project is located on the northern hemisphere and close to the equator line, one of the design challenges was to reduce the solar exposure especially on the north and south facades. This required a performance-driven design analysis approach in order to offset the solar exposure amount. Therefore, with the sun position in mind, this façade panel will have flexible parametric geometry and its size will be affected so that the higher solar radiation, the smaller the stretch mechanism will be. The different design variations for the façade paneling utilized in this building envelope considered a more responsiveness to the environment which can influence the interior space.

The geometry for the parametric facade panel types is created in Revit ® and positioned to wrap the building envelope of the building. The configuration of panels introduces the definition of fabric-like covering the building mass. The facades are occupied by a simple rectangular panel type (figure 8). The bottom two edges of the panel are assigned “X1” and “X2” parameters so that to stretch and retract and control the size of the opening/shading area. Each panel within the facade sub-divide surface (UV tiles) is assigned a panel definition according to two AID values to describe the variation of the solar exposure and privacy values. Using the RGB colour values from AID image, several design iterations are produced for the facade fabric.

Most of this work depended on the execution of the rules previously mentioned in sections 2.3 and integrated into the PattternGen add-on to express the façade pattern. The explorations of different patterning scenarios in the project case study were the product of traditional feedback interaction between the design team based on a variety of AID images. Most of the variations in parametric panel size added to the building facades were combinations of reaction to solar exposure, as well as preserving the interior space privacy. Such combinations also introduced to this workflow a more flexible configuration to the design process. The ability to provide more views from inside to outside has been achieved by the stretch/retract mechanism in the panel geometry. Similarly, the different panels were positioned on the façade in accordance with the AID image pixel properties which maps the adds/remove panel placement per the greyscale used in the AID image.

5. APPLICABILITY AND KNOWN LIMITATIONS

There are several application and limitations relating to this work in its current development and the how it may shape the current state of architectural design practice. The AID-image overlay approach here is a proof-of-concept and is based on interaction between the user and the computational design process. The practical application of this approach over intense code-based computation approaches are the following:

1) Reducing the gap between theory and application in practice by means of integrating interface without interfering with the normal design process workflow. Designers would have the tendency to adopt it as they require more comfort level and familiarity with the initial set-up of the program.

2) Exploration of different schemes is likely to be more anticipated since the approach needs less design computation skills that many designers do not have. This approach allows them to focus on design tasks and less on software coding.

3) The required level of design-abstraction to iteratively explore complex geometry is appreciated especially when the design concepts are still in an early scheme development.

4) The generations of executed design schemes are within the same Revit BIM environment which makes it practical to transition easily to a later more developed design stage.

5) The AID-image overlay approach creates a simple computational design workflow for best practice and allows the user to iterate design test-runs development.

The current limitations and areas for improvement are provided below:

1) As explained earlier, the customized PatternGen add-on is developed to work with Autodesk Revit Architecture application which demands that users have familiarity with Revit conceptual/parametric modelling environment.

2) Although the current development was geared towards using a simple rectangular “UV” facade grid pannelization, our experiments with other Revit default “UV” surface patterns like (triangular, diamond, rhomboid, etc.) were successful. This development figures out the problem when applying non-rectangular “UV” grid is due to incompatibility between the image pixel counts and the total facade panels’ count.

3) Like the development of many parametric tools at initial phase - the AID approach focused on setting a framework for generating façade design alternatives. Peter (2012) explained that a detailed daylight analysis or energy façade modelling at very early design stages may be inappropriate and time-consuming. Therefore, the simplified framework was structured around AID image overlays as common rule-of-thumb that might assist the generation of façade design alternatives. In the long run, this development can transition to further embed fast, numeric, quantitative optimization feedback loop. Rules and constraints can be added for optimization purposes to compare decisions between alternatives against specific design criteria. However, this research will not emphasize on these issues due to the limitations of its scope.

6. CONCLUSIONS AND FUTURE DIRECTIONS

This paper presented a computational design approach for dynamic façade patterning design based on parametric thinking. An automated façade panelization control mechanism approach and custom add-on tool have been described that implements generic parametric rules to overcome the complex methods relying on heavy scripted programming. In this regard, several illustrations for the design method supported with a case study have shown the potential in the generation and exploration of design alternatives by directly linking external AID values to patterning the facade surface. The case study also provided an applicable example of attempting to rationalize the method of parametric thinking to reduce the lengthy time spent when creating the desired design directions. The designer can alter the panelization of the façade by setting up a parametric process combined with the rules and image-pixel data while maintaining promise for architectural articulation to be discovered.

The proposed AID overlay approach for panelling the building facades triggers design ideas as a practical method for exploring new types of shapes as an interface between digital design, process, and analytical data. The work here also attempted to build on the research works gathered to expand BIM capabilities by providing a hybrid design process. Although computational design methods and software tools are widely spread in academia, the greater picture of parametric thinking encounters much challenge in professional practice. This work identified that AID is one of the approaches to manage facade patterning iterations interactively. It also showed that the ability to deal with design complexity effectively at early design phase. Incorporating parametric tools has provided a new way for exploring façade design and automation.

With regards to future work, the new generations of design specialists will need to be educated on the knowledge of computational geometry, scripting, and parametric data model management. This also will require an appropriate time and commitment to multidisciplinary team collaboration. Another implication from the vision in this work is that design professionals may act as a tools-makers dealing with complex design tasks which may open broader opportunities for abstracting parametric design thinking functions and operation. Indeed, the PatternGen(c) add-on development demonstrated the advantages customizing design application software like Autodesk ® Revit that are widely used by architectural designers, but hardly utilized in computational design field. This in turn can supports further extensibility for its capabilities and incorporating further features of interactive computation design. One desirable future extension to this work would be to incorporate further aspects such as a feedback loop of optimizing the results from the configured façade. To this matter, attempts can be made to use the saved façade parametric panel properties to further assist the designer with decision making based on optimization and analysis of different scenarios. One of our intents is to expand the scope of this AID overlay approach and include other relevant features such as: (1) to have seamless digital connection with kinetic façade prototype, (2) more research into performance-based design.

REFERENCES

- AISH, R., AND WOODBURY, R. (2005). “Multi-level interaction in parametric design.” Smart Graphics 2005 Conference Proceedings: International Symposium on Smart Graphics, Frauenworth Cloister, Germany, pp. 151–162.
- BARRIONUEVO, L., LOPEZ, R. AND SERRENTION, R. (2004). Spirospaces in Architectural Design. 1st ASCAAD International Conference in e-Design in Architecture (December 2004), KFUPM, Dhahran, Saudi Arabia, pp 13-33
- BEAMAN, M. AND BADER, S. (2010). “Responsive Shading | Intelligent Façade Systems”, ACADIA Conference Proceedings, Life in:Formation, New York, USA, 2010.
- EARL, C. (2000). Cues and Contingencies in Shape Computation. In Greenwich International Symposium in Digital Creativity (January 2000), the University of Greenwhich, pp 479-487
- FRAZER, J. (1995). An Evolutionary Architecture, the Architectural Association, London, UK, E.G. Bond Ltd.
- HARFMANN, A. C. (2012), ‘Linking Detailed Solar Collection Data to a Parametric Model for Accurate Performance Analysis Throughout the Design Process’, International Journal of Architecture, Engineering and Construction, Vol. 1, No. 1, March 2012, pp. 37-46.
- HUDSON, R. (2009), ‘Parametric Development of Problem Descriptions’, International Journal of Architectural Computing, Issue (2), Vol. 7, June 2009, pp. 199-216.
- LUEBKEMAN, C. AND SHEA, K. (2005), ‘Computational Design + Optimization in Building Practice’, the Arup Journal, Vol. 3, 2005, pp. 17-21.
- MADEDDU, D. (2011). “Interactive Facade Optimized for Daylighting and Pedestrian Response Using a Genetic Algorithm”, Generative Art XIV Conference Proceedings, Edited by Celestino Soddu, Rome, Italy, pp. 508–514.
- MCFADZEAN, J. (2000). Analyzing the Creative Process in Architectural Conceptual Design. In Greenwich International Symposium in Digital Creativity (January 2000), the University of Greenwhich, pp 479-487
- TURRIN, M., BUELOW, P., KILIAN, A. AND STOUFFS, R. (2012). Performative skins for passive climatic comfort: A parametric design process. Journal of Automation in Construction, Vol. 22, March 2012, pp. 36-50
- PARK, K. AND HOLT, N. (2010), ‘Parametric Design Process of a Complex Building In Practice Using Programmed Code As Master Model’, International Journal of Architectural Computing, Issue (3), Vol. 8, September 2010, pp. 359-376.
- PARK, S., ELNIMEIRI, M., SHARPE, D.C., and KRAWCZYK, R.J. (2004). “Tall Building Form Generation by Parametric Design Process”, CTBUH Conference Proceedings, Tall Buildings in Historical Cities - Culture & Technology for Sustainable Cities, Seoul, Korea, October 2004.
- RORIG, T., SECHELMANN, S., KYCIA, A., AND FLEISCHMANN, M. (2014). ‘Surface Panelization Using Periodic Conformal Maps’, Edited by Philippe Block, Jan Knippers, Niloy J. Mitra, Wenping Wang, Advances in Architectural Geometry 2014, Springer, London, UK, pp. 197-214
- SCHUMACHER, P., (2009). Parametricism: A New Global Style for Architecture and Urban Design. Architectural Design 79: pp. 14-23