Transformative Pixels

Computational color and image displacement in generative and representational design

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This paper presents Images as Instruments, a computational design seminar taught at Yale University in 2024, exploring how digital images can serve as both generative and representational tools in architecture. Reframing the digital image as a computational color and pixel-based dataset, the seminar foregrounds image-processing techniques—filtering, moshing, warping, and displacement mapping—as spatial and tectonic methods. The study adapts displacement mapping from computer graphics into architectural workflows by translating pixel intensity values into volumetric deformations and material articulations. Through assignments, students constructed image-driven wall systems and voxelized building chunks, using digital color and chromatic algorithms as design parameters. These workflows enabled students to move fluidly between image curation, spatial translation, and material construction, culminating in design outcomes that challenge traditional form-making pipelines. Case studies demonstrate how computational imaging logic can guide generative form-making,tectonic assemblies, embed memory and narrative, and generate expressive surface material conditions. Rather than treating images as symbolic or ornamental, the seminar situates them as structural and epistemic devices—central to postdigital design thinking. This research contributes to ongoing discussions in computational pedagogy and new materialism by positioning image displacement as a critical method for expanding architectural representation, authorship, and material expressivity within digital design methodologies.

Keywords: *Confluence, Computational Color, Image Displacement, Computational Design, Image Processing, Generative Design, Computational Pedagogy, Form-making.*

INTRODUCTION

In the context of the postdigital condition, the ever-expanding repertoire of digital media and computational tools has not only radically altered the conventions of architectural representation and materialization—it has also redefined how architecture is conceived and perceived. Among the most profound shifts is the repositioning of digital images. Once understood as static visual references or polished outputs, digital images have evolved into active datasets capable of informing spatial generation and tectonic articulation. Composed of pixel-based numerical information, the image now serves not merely to depict but to compute, offering a new lens through which to engage material form, visual language, and architectural atmosphere.

This paper presents *Images as Instruments*, a computational design seminar taught at Yale University in t2024 which investigates how digital color, image processing, and displacement mapping can function as both generative and representational tools in architectural workflows (Figure 1). The seminar centers on the image not only as surface or symbol, but as structured data capable of encoding and informing design decisions across multiple scales—from texture to structure. Through filtering, moshing, warping, and displacement mapping, students learned to extract, manipulate, and reinterpret visual information into spatial and material systems. These operations encourage a shift in architectural thinking: from geometry to pixelation, from form-making to image-curation, and from design intent to postproduction logic.

Figure 1
The original painting Portrait of an Artist (Pool with Two Figures) by David Hockney 1972) (left) is converted into a grayscale displacement map (center), where brightness values control vertical extrusion in 3D space. The original image is simultaneously applied as a diffuse color map (right), wrapping visual content onto a mesh geometry, thereby unifying representation and form. (Source image used for educational, non-commercial purposes.)

This investigation aligns with the eCAADe 2025 conference theme of *Confluence*, which calls for rethinking the convergence and divergence of paradigms in architectural design. This research responds by positioning the digital image as a point of confluence—where form-making, representation, computation, and material thinking merge. It argues that images are not merely figural surfaces but operative fields whose chromatic values, resolution, and structure can be computationally encoded to drive architectural invention.

The objective of this paper is twofold: first, to articulate a methodology for image-based design that reframes image manipulation as a spatial and tectonic operation; and second, to evaluate its pedagogical and conceptual implications through case studies from the seminar. In doing so, this paper contributes to broader conversations about computational pedagogy, postdigital authorship, and the evolving role of image-based data in architectural thinking and practice.

BACKGROUND AND THEORETICAL CONTEXT

This study is situated within evolving discourses around postdigital aesthetics, computational color, and image-based design methodologies in architecture. The term *postdigital* refers not simply to the use of digital tools, but to a cultural and epistemological condition in which computation is fully embedded within design practices, aesthetics, and pedagogy. As Carpo (2017) has argued, we are no longer in a moment of novelty around digital technologies but in a paradigm where "the digital is the norm, not the exception."

In this context, the digital image emerges as a primary medium for design speculation—capable of informing both the representation and generation of architecture. Unlike their analog predecessors, digital images are structured datasets composed of discrete pixels, each defined by numerical values in RGB (Red, Green, Blue), HSB (Hue, Saturation, Brightness), or other color systems. This numeric legibility allows for both precise manipulation and computational parsing, enabling architects to use images not only as visual references but as active data sources. As Gonzalez and Woods (2018) emphasize, digital image processing is "a type of signal processing where the input is an image and the output may be an image or features extracted from it."

The pedagogical foundation of this study draws from both visual culture and technical computation. Albers' *Interaction of Color* introduced the contextual and perceptual dimension of color—how it shifts based on adjacency, background, and lighting (Albers, 2006). In the digital realm, this logic extends to programmable manipulation, where chromatic intensity can serve as a modulator of spatial thickness, structural rhythm, or surface articulation. Kane (2014) traces how digital color evolved from early experimental aesthetics to become a standardized visual system across industries, arguing that digital color operates in both subjective and numerical registers—mirroring the course's use of color data as a parameter of formal variation.

Beyond color theory, this methodology also resonates with media studies and computer graphics. May (2019) and Haeusler (2009) have framed digital images as performative and computational mediums—not passive depictions but active visual technologies embedded with structure, logic, and intent. Image properties like resolution, layers, and bit depth can be read architecturally: resolution functions as a form of Cartesian order; layering parallels compositional depth; pixel grain corresponds to material texture (Figure 2).

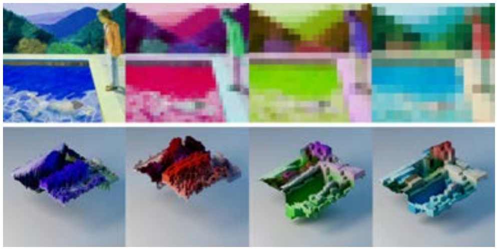


Figure 2
Pixelated reinterpretations of David Hockney's Portrait of an Artist (Pool with Two Figures 1972) illustrate how image resolution can drive spatial formation. The top row demonstrates varying degrees of pixelation, each reducing visual detail into blocky hue zones. In the bottom row, hue values from the pixelated images are mapped to vertical extrusion values in 3D space, generating voxel-based architectural forms where color becomes both a representational and generative input. (Source image used for educational, non-commercial purposes.)

Displacement mapping, a core method in the seminar, originates from the domain of computer graphics and rendering. First introduced by Cook (1984), displacement was developed to simulate surface details by altering vertex positions according to grayscale image values. While its primary application was visual realism—such as shadows, occlusions, and surface roughness—it holds significant untapped potential as a form-making tool in architectural workflows. This approach aligns with current research in media art, where artists such as Menkman (2011) and others in the glitch community reframe digital distortion as a method for aesthetic and conceptual critique (Lovink and Daniels 2010).

By merging theoretical perspectives with computational practices, this seminar embraces a postdisciplinary pedagogy—where the digital image becomes a confluence of design media, computational logic, and cultural expression. It moves beyond traditional divisions of drawing and modeling, representation and generation, image and material, positioning the image as a hybridized design medium for contemporary architectural inquiry.

METHODOLOGY

The methodology centers on the image as an active computational medium—capable of generating form, guiding representation, and informing material logic. Rooted in the premise that image is a structured dataset, the seminar reframes image manipulation as a computational operation rather than a post-production effect. Students explored sequential workflows that collectively examined how visual information could be transformed into architectural systems. This included color filtering, image warping, glitch aesthetics, and, most importantly, displacement mapping. Each method was presented not just as a technical tool but as a conceptual device, opening architectural design to questions of perception, authorship, and materiality.

Digital Images as Computable Design Fields

Composed of pixels with numerical intensity values, digital images are inherently quantifiable. This structure can be parsed, filtered, and reinterpreted through computational logic. As Gonzalez and Woods (2018) explain, digital image processing enables the extraction of features or transformations directly from image data, offering new ways to perceive, measure, and design with images.

In architectural terms, pixel-based structures become analogous to modular systems: resolution mimics grid logic, color channels become formal parameters, and grayscale brightness values inform spatial thickness and surface relief. Drawing from Albers' theory of contextual color (Albers 2006) and Kane's study of chromatic standardization in digital aesthetics

(Kane 2014), the course emphasized perceptual and programmable dimensions of digital imagery. Color and pixel data thus shifted from symbolic to structural—becoming measurable, manipulable, and materially operative.

Filtering, Moshing, and Warping as Image-Based Operations

Image processing involves algorithmic operations to analyze, manipulate, and extract data from visual input. Though not originally developed for architecture, these techniques are embedded in design software and increasingly shape our practice. Students were encouraged to deconstruct the "black-box" nature of technologies by analyzing their mathematical logic and translating them into design workflows.

- **Filtering** applies algorithms to enhance, suppress, or extract specific features from images, emphasizing visual and tactile qualities. It involved techniques such as edge detection, dithering, halftoning, thresholding, and convolutional smoothing. These operations allowed students to isolate textures, detect gradients, and abstract visual patterns into design systems. As Szeliski (2010) notes, filters amplify or suppress spatial frequencies, offering designers a way to extract latent geometries (Figure 3).

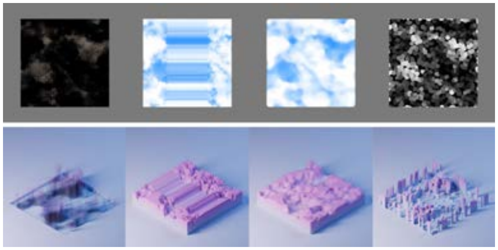


Figure 3
Image-processing techniques (top row) generate diverse displacement maps, each encoding pixel-based brightness values into grayscale information. These are then used to produce distinct 3D geometries (bottom row)

- **Moshing**, adapted from glitch art and media theory, introduced methods of intentional disruption. Techniques like RGB channel shifting, pixel sorting, and databending were used to destabilize normative readings of images. This expanded the aesthetic and conceptual range of student work, drawing from practices studied by Menkman (2011) and Lovink and Daniels (2010), who argue that glitch is both a rupture and a revelation of system logics. Students explored how these disruptions could systematically influence architectural outcomes (Figure 4). This technique emphasized the potential of digital disruptions to enhance creativity while maintaining scalability for design iterations.

Figure 4
Pixel sorting applied as an image moshing technique (left), producing a vertically fragmented chromatic field. This processed image is then used both as a diffuse color map and a displacement map for a voxelized 3D object (right). The diffuse map defines surface color, while the displacement map uses pixel brightness values to generate surface protrusions and relief.

- **Warping** extended image logic into spatial dimensions. Students manipulated image geometries through affine transformations and morphological operations, including scaling, rotation, dilation, and erosion. These geometric distortions became spatial artifacts through translation into mesh geometries, grids, and voxel fields, enabling students to explore continuity, deformation, and structural irregularity. These transformations were introduced as spatial techniques that reshaped image data into form, drawing connections to practices in texture mapping, animation, and 3D modeling (Manovich, 2001).

These operations, taught in both code-based and CGI-based environments (e.g., Processing, Photoshop, Grasshopper, Cinema4D), were deeply contextualized. Students learned not just how to apply techniques, but how to understand

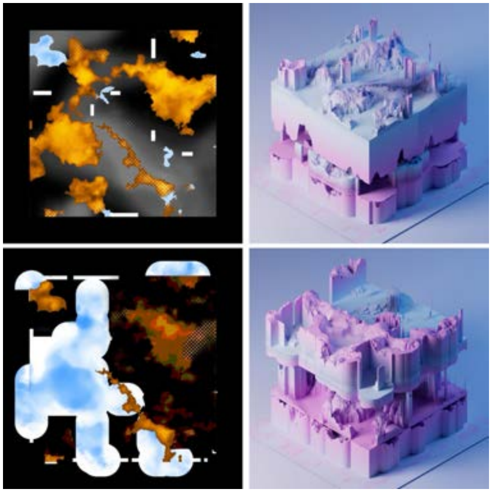
Figure 5
A two-story spatial assembly derived from stacked image sets of displacement and alpha cutout maps (right). The image on the left shows the composite displacement map used for the top floor. By varying the direction and intensity of displacement across multiple image layers, the resulting geometry demonstrates the coexistence of high-resolution detail and low-resolution abstraction within a unified form. This illustrates how image manipulation techniques can simultaneously produce differentiated spatial expressions and architectural resolution.

the computational logic beneath them and speculate on their architectural implications.

Displacement Mapping as Generative and Representational Technique

The most critical methodological tool in the seminar was displacement mapping. Originally developed for rendering realism in computer graphics (Cook 1984), displacement mapping modifies 3D mesh geometries using grayscale image data—offsetting surface points based on pixel intensity. This allows for fine-grain surface modulation without increasing modeling complexity. In the course, students adapted this technique for architectural use—applying displacement at both the surface and massing scales to generate volumetric wall systems.

The methodology extended displacement beyond representational realism into form generation. Brightness values from image maps were used to control surface texture, structural layering, and spatial enclosure. Students deployed multiple displacement maps simultaneously—one to articulate global wall massing, another to encode material relief and surface granularity, and others for porosity, detail, and visual effect (Figure 5).



By treating displacement as a method of data translation rather than surface decoration, students explored the dual role of the image as both source of geometry and record of meaning. This approach maintained the representational origin of the image while enabling its spatial actualization. The displacement process simultaneously evoked visual reference and material result, merging what has traditionally been separated into “drawing” and “making.” As Cook (1984) notes, displacement allows rendering to reflect structural detail, occlusion, and silhouette more accurately than bump mapping—underscoring its representational power as much as its form-making capacity.

Recent advancements in displacement workflows have demonstrated their capacity to generate high-resolution, layered modulations that mimic joinery, erosion, and surface porosity (Zirr and Ritschel 2019). These insights informed how students structured their own displacement operations as spatial tools.

Workflow Integration and Course Assignments

These image-based methods were conducted through two sequential assignments:

- Assignment I: Wall as Image focused on tectonic analysis and image transformation.

- Assignment II: Architectural Voxelization and Chunk Models developed image data into volumetric wall prototypes.

In the first assignment, students selected a conventional wall type (e.g., masonry, timber stud, cavity wall, steel brace, CLT) and analyzed its material, structural, and historical logic. Concurrently, they applied image processing workflows—filtering, moshing, and warping—to develop image maps aligned with their wall’s performance or expression.

Crucially, students were asked to establish a meaningful correspondence between tectonic assembly and image transformation. The wall was treated not as a static section but as a dynamic image-to-form transformation, animated and documented through renderings, layered diagrams, and temporal explorations.

Image transformation was never arbitrary; instead, it was deployed to critically augment or reveal aspects of the wall system's spatial, material, and compositional characteristics. Outputs included filtered imagery, displacement models, and short animated simulations that foregrounded image-based temporal variation and material behavior/

The second assignment invited students to develop voxelized wall models embedded within a building "chunk." Here, students used at least three image maps—diffuse (color), displacement (height), and alpha (cutout)—and in many cases extended the workflow to include roughness, reflection, and normal maps as part of a full PBR material pipeline. These images governed how walls behaved across multiple design layers: from grain orientation to surface porosity, from massing modulation to joinery expression.

The chunk model also re-situated the wall as a spatial and conceptual node. Rather than treating it as a façade or surface, students explored its embeddedness between ground and roof, its thickness and poche, its potential for ornament, and its role in programmatic articulation.

Deliverables included filtered images, layered image maps, digital voxel models, rendered animations, and physical prototypes. These outcomes affirmed the methodological goal of the seminar: to convert representational data into generative design workflows grounded in visual logic, tectonic agency, and computational literacy. Together, these workflows emphasized **methodological continuity**—students iteratively cycled through sampling, filtering, mapping, voxelizing, and interpreting image data. Rather than following a fixed form-generation pipeline, they authored their own transformation processes. The result was a diverse range of spatial outcomes unified by a shared computational literacy and critical image culture. (Figure 6).

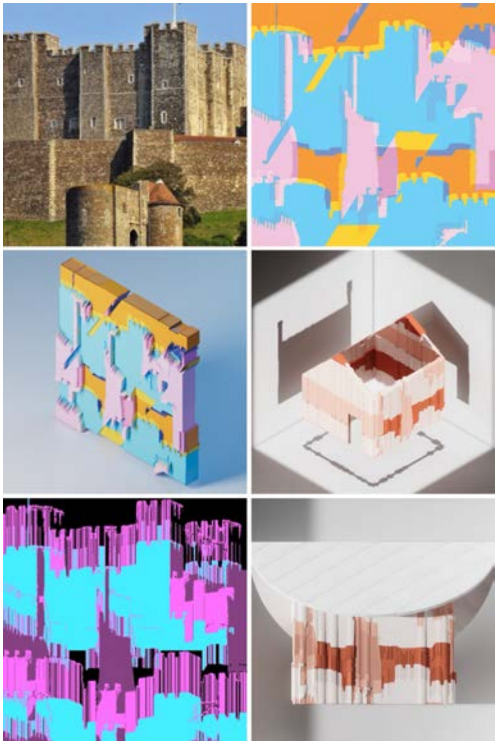


Figure 6
A series of experiments using image filtering, moshing, and displacement mapping to generate a wall system composed of interlocking voxelized units. These units exhibit a range of visual and material effects—varying in scale, grain, and figuration—while referencing architectural typologies and chromatic abstraction.

IMPLEMENTATION AND CASE STUDIES

From reinterpretations of vernacular construction to expressive renderings of memory, erosion, and transformation, the assignments demonstrated the generative power of image logic in postdigital design practice.

The following six projects illustrate the conceptual diversity and technical depth explored in the seminar. Each is organized around three key categories: (1) wall construction system, (2) conceptual narrative, and (3) image-based method.

Masonry Wall: Image Resolution as Temporal Excavation

Investigating the remnants left behind by building demolition, the project transforms the party wall into a layered temporal artifact. It reveals traces of the past while speculating on future spatial possibilities, embedded within the material strata of masonry.

The wall composition emerges from three distinct image layers (Figure 7). The integration of these layers via displacement and texture mapping yields a masonry system that embodies representational and generative ambitions simultaneously.

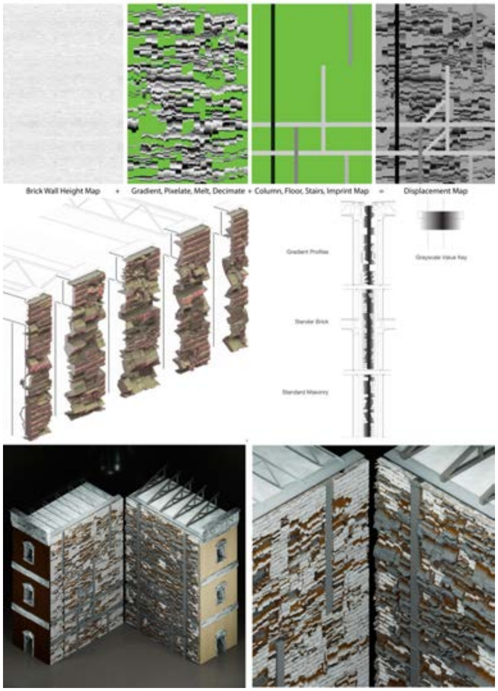


Figure 7 (Credits: Lucas Gillie, Mehmet Rizaoglu)

The base layer samples brick textures to define normative visual reference. The middle layer employs a horizontal gradient map subjected to pixel sorting, resolution fragmentation, and local displacement by applying pixelate, melt, and decimate techniques to generate a spectrum of carved profiles at three scales: carved profiles, slender bricks, and standard masonry. Each modulates in a relief-like fashion from locally displaced grayscale values. The top layer—a low-res compositional silhouette—introduces figural elements such as stairs, voids, and slabs.

CLT Panel Wall: Postdigital Blank through Compositional Disruption

This project challenges the standardization of the CLT panel by using postdigital aesthetics to recompose fiber orientation, member relationships, and surface logic. Through compositional disruption, the CLT blank is transformed from a modular element into a responsive design surface.

Displacement maps based on manipulated wood textures were overlaid with pixel sorting, stretching, and layering effects. Orientation of grain patterns informed internal layering logics, influencing joinery and connective behavior across panels. Diffuse, alpha, and hieght maps were strategically used to produce apertures, voids, and material shifts within the composite CLT system. The final chunk model presents a materially aware reinterpretation of standardized wall assemblies, emphasizing the role of imaging in redefining tectonic logic (Figure 8).

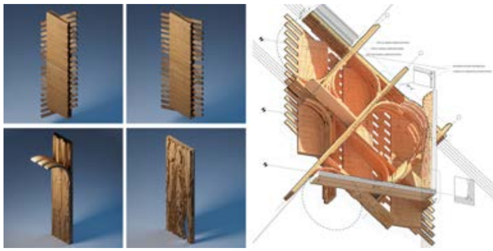


Figure 8 (Credits: ustin Levelle, McKenna Sabon)

Thatch Wall: Material Gesture through Multi-Directional Displacement

The project reinterprets the expressive material logic of thatching as a computationally mediated gesture, drawing on Roland Barthes' notion of "surplus action" to emphasize indeterminate excess in making (Figure 9).

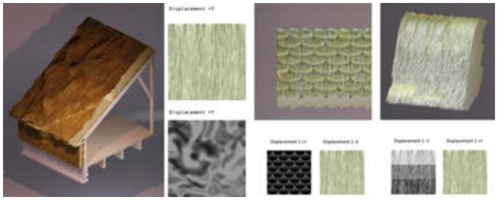


Figure 9 (Credits: Bryan Wang, Elis (Xingyue) Huang)

The design employs two stages of displacement mapping to articulate the form and detail of the thatch system. The first stage defines the global massing of the roof, while the second fine-tunes local material texture using bitmap-based directional displacement. This layered process reveals how pixel-level manipulations can yield effects that are difficult to model geometrically—retaining the tactile spontaneity of the original construction technique while reconstituting it through computational logic.

Tile Wall: Khrushchyovka as Memory-Based Translation

Rooted in personal memory and regional specificity, the project reimagines the tiled facades of Soviet-era Khrushchyovka housing blocks as memory archives. The tiles become signifiers of time, decay, and place—transforming prefabricated uniformity into individual expression.

The project makes innovative use of filtering, moshing, and analog image-editing methods (e.g., hand gesture based painting and stamping) to process photographic references into layered maps. These maps were displacement- and texture-mapped onto a wall model to express material erosion, regional variation, and temporal patina. Through this translational method, the project visualizes memory, imagination, and perception as tangible architectural form, embodying both generative and representational design modes (Figure 10).

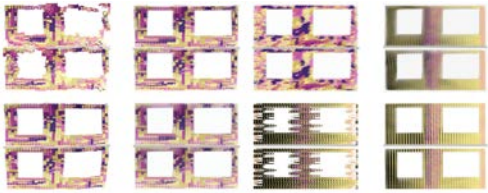


Figure 10 (Credits: Aysel Aziz, Mesut Sallah)

Stud Frame Wall: Picturesque Assembly through Voxel Layering

The project reinterprets the timber frame wall as a compositional apparatus, exploring how image layering and opacity can inform joinery complexity and spatial legibility. It asks how digital image tectonics—positioning, orientation, transparency—can substitute for traditional geometric assembly.

Drawing on picturesque conventions, students layered and composed filtered image fragments using noise, blur, transparency, and masking. These composites were voxelized into structural units that reflect both image geometry and frame syntax. The result is a wall system that is readable both as architectural detail and as image artifact—where visual representation becomes inseparable from material articulation in a postdigital framework (Figure 11).

Figure 11 (Credits: Frieda Kickliter, Sarannya Sharrma)

Metal Brace Wall: Ornamentation through Structural Imaging

Inspired by Fernand Léger's *Mechanical Elements*, the project repositions structural bracing as visual ornament and spatial pattern. Transparency, strength, and light are treated as formal agents shaped by machine aesthetics.

Patterned images of steel structures were processed through RGB filtering, manual masking, and roughness mapping to create displacement-ready maps that define the structural language of the wall. The result is a wall system in which metal bracing is visually articulated and spatially composed, not simply as structure but as expressive element. Custom maps enhance material legibility, bridging ornament and tectonic articulation within a digitally cohesive logic (Figure 12).

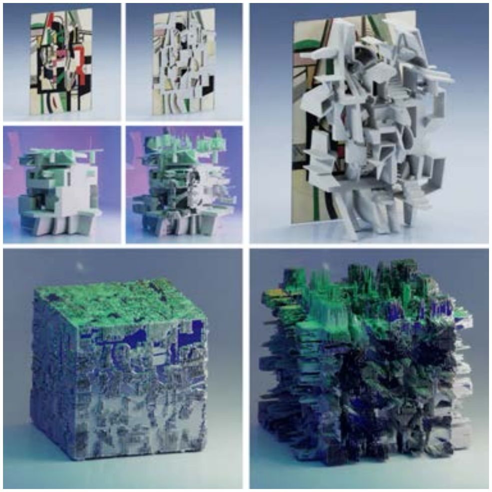


Figure 12 (Credits: Aigeirm (Aiko) Khamar, Narye Han)

DISCUSSION

This paper has demonstrated how computational image workflows—particularly filtering, warping, moshing, and displacement mapping—can expand architectural design pedagogy beyond geometry-driven parametrics into a more nuanced, media-rich postdigital framework. In Images as Instruments, students treated digital images not as secondary representational artifacts but as active datasets with spatial, tectonic, and conceptual agency.

By repositioning color and pixel-based data as operative media, the seminar emphasized how image processing can bridge form generation, material articulation, and representation. Displacement mapping—adapted from computer graphics (Cook, 1984)—emerged as the pivotal technique within this methodology. Its capacity to convert 2D pixel values into 3D surface deformations enabled students to explore formal articulation, tectonic modulation, and perceptual effects within one continuous workflow. Displacement was used to generate topography, embed joinery systems, simulate erosion, or introduce figural cues—all derived from image data. This duality of form and representation allowed students to oscillate between descriptive and generative modes of practice.

Critically, the assignments positioned students not simply as image users but as authors of visual systems. They were required to design their own image maps, establish relationships between visual logic and tectonic effect, and construct wall systems that engaged architectural history, construction technique, and media culture. The image was treated not as ornament, but as an epistemic and generative device—capable of carrying memory (Kane 2014), structural rhythm (Albers 2006), or postdigital commentary (Menkman 2011; Lovink and Daniels 2010).

Furthermore, by breaking the "black-box" operations of software, the seminar promoted software literacy and methodological authorship. Students moved fluidly between Photoshop, Rhino, Processing, Cinema4D, and rendering engines—not to produce predefined effects, but to construct pipelines of transformation. Image filters, channel separations, and texture maps became tools for speculation, and the iterative manipulation of digital material became a core act of design thinking. These explorations align with broader conversations in postdigital aesthetics and new materialism, where material expression is shaped by data structures and media logics (Carpo 2017; Manovich 2001). The projects demonstrated how architectural agency emerge from the reuse, reinterpretation, and reprogramming of image data—where visual culture becomes an infrastructural layer of design. The wall, as both a technical and discursive site, became the locus for this investigation.

Beyond technical workflows, the seminar opened space for critical inquiry into authorship and tool-making. Working with personal or found imagery prompted reflection on sourcing, interpretation, and appropriation. Students operated simultaneously as curators and designers—editing, filtering, and deploying visual information as form-making matter. Moreover, by exposing and reworking the internal logic of design tools, the course fostered computational literacy and encouraged students to author their own visual systems. This approach echoes Berry's (2011) call for software criticism as a mode of critical design practice—where making is also a form of thinking.

Together, these practices position the digital image at the center of architectural inquiry—where visual media become structural, and software becomes discursive.

CONCLUSION

The seminar reframes the role of digital imagery in architectural education and design. Through a sequence of computational techniques—filtering, voxelization, and displacement mapping—it advanced a method in which color and pixel data functioned not only as visual references but as generative agents in design workflows.

The projects presented reveal how image-based design enables students to translate material research, cultural memory, and tectonic logic into complex spatial assemblies. More than extending representational practice, this method fosters new forms of authorship: students become architects of processes, not merely producers of forms. In this postdigital pedagogy, design becomes a dialogue across media, platforms, and perceptual logics. Here, the image is no longer a mere backdrop to architectural invention—it is its infrastructure, its logic, and often, its starting point.

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