Anatomy of a Building

Introducing interactive RGB lenses for architectural data visualization

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The paper proposes an alternative way to present architectural information, using color filters - specifically RGB lenses - as an interface to emphasize or reveal the internal structure or hidden logic of an architectural artifact. In an interplay of analogue and digital techniques, it employs rules of color blocking in order to highlight certain aspects of complex buildings, urban plans, or interiors, which cannot be discovered using conventional visualization methods. In this research, the authors developed an interactive RGB lens-interface and techniques for superimposed color visualizations that can be used for an enhanced visualization of the internal structure of a building. By applying physical or digital color lenses, viewers can perceive individual layers of project visualizations, in order to understand certain tectonic or construction logics, such as skin, structure or infrastructure. Based on existing bibliography, the paper presents the workflow from drawing, 3D model or photograph to RGB visualization, through a series of test case scenarios applicable to the field of architecture and design.

Keywords: *architectural visualization, color & light, subtractive color mixing, RGB lenses, post-digital, building anatomy*

INTRODUCTION

RGB visualizations, which reveal themselves only when seen through a color filter, are widely known from artworks, science shows, books (Demois and Godeau 2014) and board games [3]. They often have the form of encoded messages that can be read with the use of decoder glasses, also called magic lenses. When seen in white light and without the glasses, these multi-layered color visualizations often seem chaotic to the viewer. Consisting of layers with superimposed information, they are intentionally confusing to the eye, in order to conceal certain information. Different parts or layers of the images are revealed when the color of the light changes, or when seen through a colored lens. This representational strategy for hiding or revealing information can be applied to different scales - from urban scale to product design - offering an insight into the anatomy of a building or object.

PRECEDENTS IN THE USE OF LENSES FOR VISUALIZATION

There are several precedents of the use of lenses for visualizations. This research draws on different dis-

ciplines to investigate this concept in order to find new uses for lenses in visualization, and to extract the knowledge that could be applicable to architecture.

A moveable filter can be applied as a user interface tool that is placed above an image, similar to a magnifying glass. Thereby, the appearance of the objects in that specific region is changed, helping viewers to understand different aspects of visual information (Stone et al. 1994).

Bier et al. researched visual filters, called "Magic Lens" filters, which are transparent or semi-transparent user interface elements "that modify the presentation of application objects to reveal hidden information, to enhance data of interest, or to suppress distracting information" (Bier et al. 1993). These are digital widgets that can be applied to a 3D model, in order to view a selected region of interest as wireframe or magnified, or - in combination - as magnified wireframe.

Depending on their function, some lenses can be used on color as well as on black-and-white images (e.g. magnifying glasses), whereas others can only be used on color images with specific properties (e.g. decoder glasses).

The basic concept of color lenses as filters was developed in the pre-digital era, often referred to as "decoder glasses", where both lenses are the same color (i.e. blue, red), revealing hidden messages when looking through them. Color lenses have also been used to achieve stereoscopic views and anaglyphs, using the well-known - and currently considered "retro" - red/blue glasses, or digital hardware like 3D shutter glasses. To be able to use color filters on images, these images need to have certain properties. The filtering concept may be based on additive or subtractive color mixing (see chapter "How to Build an Architectural RGB Visualization").

Colors are extensively used for visualization purposes, like semantic labeling and remote sensing (Audebert et al. 2017), scientific diagrams with pseudocolor, RGB representations of height maps or physical properties. Oppositely, superimposed color images - with color-coded information or illustrations - are used with the purpose to conceal information, which cannot be understood without decoder glasses.

Milan-based art collective Carnovsky utilizes color filtering of superimposed color images, whose appearance changes when seen in colored light or through a color lens [2]. Carnovsky pioneered shape-shifting RGB art and became famous for their experiments of visual effects of chromatic manipulation, particularly with their exhibition in the Johannsen Gallery in Berlin and their installation at Milan Design Week in 2010. Their projects consist of complex images with superimposed layers in cyan, magenta and yellow, which seem chaotic in white light, but perfectly ordered in red, green or blue light.

The Computer Graphics and Geometry Laboratory of EPFL researches reflective and refractive filters, controlling light by optimizing the geometry of the filter to produce caustic effects in the desired shape (Kiser et al., 2013). They use high contrast color caustics, lighting a piece through a refractive multicolor filter, to achieve a projected image in the color of the original image (Schwartzburg et al. 2014).

APPLICATIONS OF COLOR FILTERS IN ARCHITECTURE

Colored filters have been extensively used in architecture in the form of glazing - from Islamic glass decoration in mosques, over architecture classics such as the Ronchamp, to the work of contemporary architects and artists such as Steven Holl and Olafur Eliasson. The use of colored glazing in buildings has the ability to change the atmosphere and the perception of colors in the interior. This has always held an important role in religious architecture and in contemporary cultural buildings, museums and art exhibitions.

Similarly, RGB visualizations present a great potential for the representation of architecture and urban design, as the encoded layers of information can reveal the internal structure of a building or cast light on different components of an urban plan such as built volumes, green spaces, circulation, pedestrian

flows and infrastructure.

The benefits of RGB visualizations lie in the fact that certain aspects or features can be isolated and presented, providing insight into the anatomy of a building or a product. They can form an alternative to exploded axonometric views or other infographics, enabling clients, audience or students to obtain an enhanced understanding of a project, by hiding or revealing information on demand. RGB visualization may be used as a tool to present or instruct, creating an interactive experience of space and information.

Elements that can be represented in RGB images include human and traffic flows, urban maps, vertical communication in high-rise buildings, classification of spaces such as private and public, facade constructions, structural elements such as space frames, slabs and cores, as well as forces within structures (topological optimization).

ANALOGUE AND DIGITAL VISUAL FILTERS - A POST-DIGITAL APPROACH

In 1995 Feiner et al. introduced the use of emerging technologies of augmented reality to "illustrate, understand, and modify architectural anatomy" (Feiner et al. 1995). The aim was "to explore relationships between perceived architectural space and the structural systems that support it, to help understand architecture in ways that are impossible to achieve by simply viewing the perceptual reality of completed spaces" (Feiner et al. 1995).

The methodology for RGB visualizations presented in this paper aims to employ a combination of digital and analogue techniques, re-visiting old tools and utilizing them in a new context. This is in accordance with Mark Burry's suggestion with regards to digital media, that "before we abandon old tools for new, this is a good moment to put the brakes on. Hybrid activity demonstrates unequivocal benefits to the design process" (Burry 2005).

In line with the post-digital tendency to re-visit traditional tools, this research suggests a novel use of decoder glasses for architectural visualization, with the aim to engage the viewer, and to enable her/him to selectively view certain aspects of a building in an interactive and playful context. It represents an attempt for disenchantment with purely digital tools and a revival of "old" media, understanding terms like "post-digital" or "retro-analog" as a hybrid of "old" and "new" media (Cramer 2015).

While the term "post-digital" discusses the "contemporary revival of analogue technologies" (Thoren et al. 2017), it also questions the "presupposition of binary divisions between the dichotomies 'users'-'non-users' and 'analogue'-'digital'" (Thoren et al. 2017).

As Fure points out, the "post-digital" is not "beyond," "anti-," or simply "not" digital (2018). Instead, it is "focused less on novelty and more on the hidden aspects of computation. Post-digital design discourse calls for a critical examination of the tools and technologies we take for granted (Fure, 2018).

COMBINING ANALOGUE AND DIGITAL TOOLS FOR ARCHITECTURAL VISUALIZATION

The digital era initiated a big shift in architectural visualization. In this regard, the use of "layers" in digital imaging, drawing and modeling (such as in Photoshop, Illustrator, AutoCAD, Rhinoceros 3D) played an important role. Layers are useful to create flexible and editable images, and to keep track of the hierarchical structure of design information when dealing with complex projects.

In the pre-digital era, overlays were produced using tracing paper, transparent paper or collage techniques. The introduction of digital tools allowed architects to employ layering techniques in new ways. The current generation of architects became familiar with the concept of organizing projects in layers, and with handling their complexity by turning layers on and off. However, when aiming to transmit certain aspects of a project to non-architects, students, or clients who are not familiar with a particular project, or a digital tool, it is not always feasible to reveal different layers of visualization without the use of a compatible software. Particularly for those who are

not experienced with the organization of visual information in layers, the use of color lenses can provide an alternative and quite playful way to hide or reveal layers of architectural information.

There are several ways to visualize hidden information of buildings or to offer an insight into construction sequences and assemblies. Among the most common ones are exploded axonometrics, superimpositions and IKEA-style assembly models.

Architects such as Eisenman and Tschumi used exploded axonometric drawings, separating different elements or levels to make complex designs understandable (Figure 1). For example, Tschumi developed the project of the Parc de la Villette by the superimposition of three layers - points, lines and surfaces (Figure 2).

The above-mentioned visualization techniques are still in use today to produce informative and understandable drawings of complex buildings. For example, Coop Himmelb(l)au uses exploded axonometrics or perspectives to show construction systems or programmatic elements in the project BMW-world. Nowadays, such visualizations can be created quite easily from digital drawings or 3d-models.

Alternatively, complex information can be visualized with the proposed RGB technique. This technique exploits the benefits of digital layers in combination with analog filtering tools to create isolated views of complex buildings. It compiles a multitude of visible layers of a project to create a merged layer. The RGB visualization method is a useful tool to see the overlay of elements, while also being able to highlight different layers using the color lenses.

With the broad use of digital media in architecture, contemporary buildings have overcome the limitations of standardization, and nowadays there are buildings with unique morphology and extravagant geometry. However, for the majority of the buildings, only the external shell is visible from the outside, and information on their anatomy can only be found in specialized literature. The project "anatomy of a building" aims to reveal the hidden information about how a building functions, how it is

constructed, how it looks from the inside, or how it looked during construction phase. Having studied a great variety of buildings with such features that are worth to be shared with a broader public, the authors have undertaken a series of case studies to highlight or isolate certain pre-selected building components. The RGB images generated for this project offer an opportunity for interactive exploration of visual data, presenting an alternative way to interact with technology.
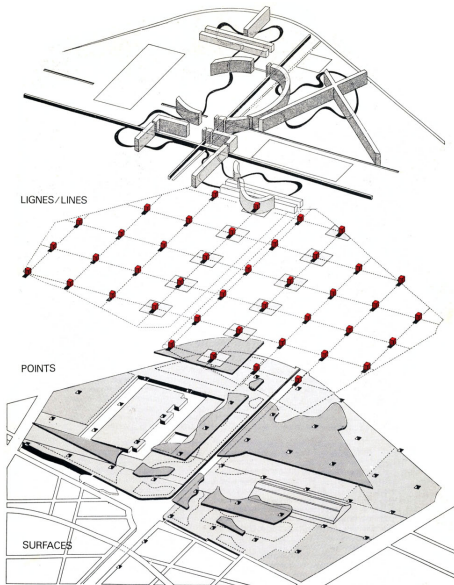

Figure 1
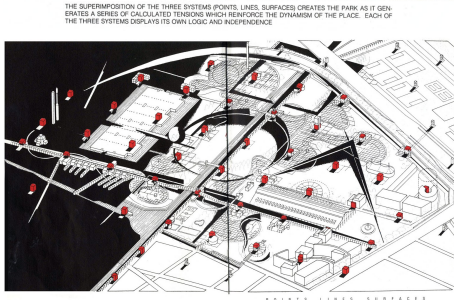Exploded axonometric of Parc de la Villette by Bernhard Tschumi (Tschumi 1988)

LIGNES/LINES

POINTS

SURFACES

THE SUPERIMPOSITION OF THE THREE SYSTEMS (POINTS, LINES, SURFACES) CREATES THE PARK AS IT GENERATES A SERIES OF CALCULATED TENSIONS WHICH REINFORCE THE DYNAMISM OF THE PLACE. EACH OF THE THREE SYSTEMS DISPLAYS ITS OWN LOGIC AND INDEPENDENCE.

Figure 2
Superimposition of Parc de la Villette by Bernhard Tschumi (Tschumi 1988)

POINTS LINES SURFACES

HOW TO BUILD AN ARCHITECTURAL RGB VISUALIZATION

This section explains the methodology used for the creation of a superimposed RGB visualization from an existing 3D model, image or photograph. The workflow includes steps in Rhinoceros 3D and Photoshop, to create the images and to test them through color filters.

Based on the color theory and on what the human eye perceives as color, the three primary colors of light in "additive color mixing", red, green and blue (known in computer industry as RGB) when mixed with each other form cyan, magenta and yellow (also known as CMY) - red+green=yellow, green+blue=cyan, blue+red=magenta (Figure 3).

In an illustration that comprises of CMYK colors, the colored lenses act as filters, absorbing all colors of light except the actual color of the lens. Therefore, decoder glasses that are red absorb blue and green light but allow red light to pass through. It is like removing certain colors of light. This principle is also known as "subtractive color mixing". In this mixing model, cyan, yellow and magenta are considered the primary colors. Therefore, a color lens subtracts all the wavelengths NOT in the color filter. In the Primary Color Wheel for light, the blue and yellow colors are placed diametrically opposite. By applying a yellow filter to magenta, this is canceling out the blue and making it appear as red.

Following the model of "subtractive color mixing", the RGB visualizations developed in this research consist of superimposed layers in CMY colors, leading to a change in the color perception when viewed through RGB lenses. The red lens (or light) filters out magenta and yellow, and highlights the cyan layer. The green lens (or light) filters out cyan and yellow, and highlights the magenta part. The blue lens (or light) filters out cyan and magenta, and highlights the yellow layer. When filtered by blue, the highlighted color (yellow) appears as black, while the white background appears in the color of the lens (blue).

The generated RGB visualizations work in conjunction with the multidimensionality of a surface, with which people can interact. They can be perceived as multicolored graphics in overlaid condition or untangled when viewed through colored filters.

A SERIES OF CASE STUDIES

In order to test the aforementioned strategy for creating RGB visualizations, the authors have developed a series of case studies, mainly based on plans, 3D models and photographs of well-known buildings and urban design projects. The projects selected are iconic buildings that due to their unique geometry, function or construction logic are worthy of our attention and analysis, and most importantly have a great wealth of secrets to reveal.

The selected buildings are:

Fondation Louis Vuitton by Gehry Partners. Gehry is a pioneer in creating buildings with complex geometries, such as the Guggenheim museum in Bilbao. The Fondation Louis Vuitton (2014) is a Cultural Center in Paris, France with a facetted free-form geometry [4]. It consists of glass sails carried by a complex steel structure, surrounding the internal cores and functions. The RGB visualization of this project allows the viewer to see not only the external skin of the building, but also the steel structure (cyan), and the internal cores and programmatic volumes (yellow, Figure 4).

Figure 3
Subtractive color mixing (image source: http://hyperphysics.phy-astr.gsu.edu/; HyperPhysics © C.R. Nave, 2017)

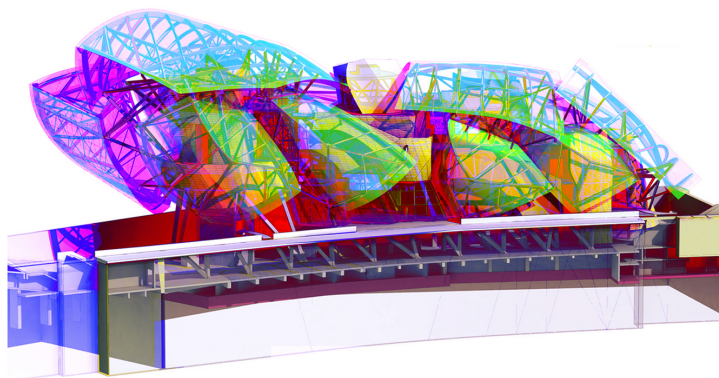Color subtraction with idealized primary filters
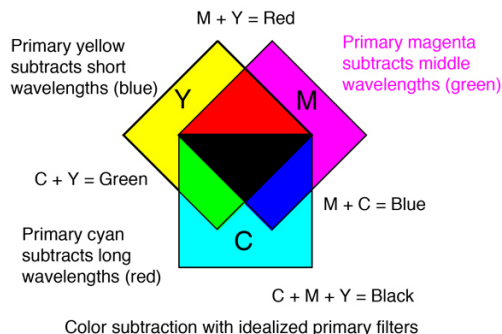
Figure 4
RGB visualization of the Fondation Luis Vuitton building by Gehry Partners. The red filter reveals the structure of the building, the green filter shows the external building skin, and the blue filter reveals the internal core of the building.
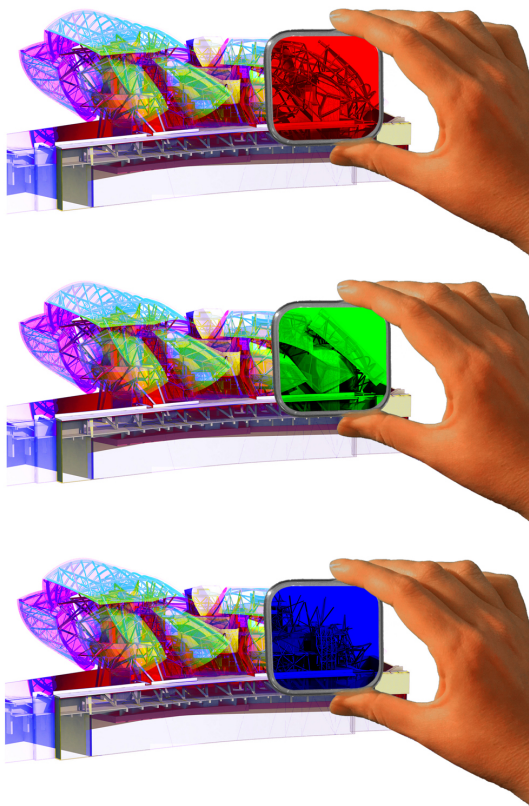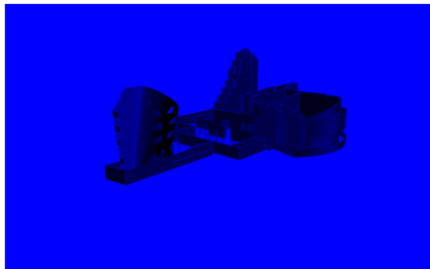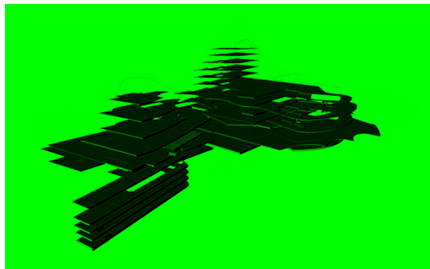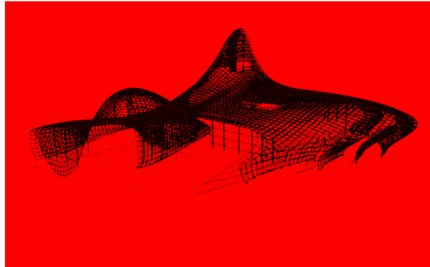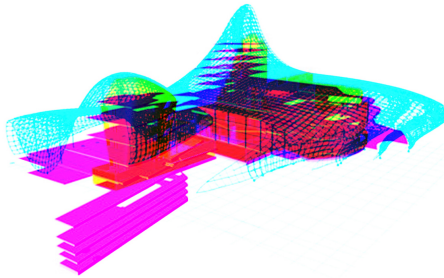
Figure 5
RGB visualization and filtered views of the Heydar Aliyev Center by Zaha Hadid Architects. The red filter reveals the structure of the building, the green filter shows the slabs, and the the blue filter reveals the internal core of the building.

Heydar Aliyev Center by Zaha Hadid Architects. Zaha Hadid is known for free-form architecture with sleek continuous surfaces, but the structure behind it is mostly hidden. The Heydar Aliyev Center in Baku, Azerbaijan (2013) is a cultural center with a fluid geometry comprising of multiple waves, emerging out of the ground. While visitors can only see the impressive homogenous facade, the presented RGB visualization gives an insight into the structural system behind the skin, consisting of a steel framework combined with a concrete structure of cores and slabs [5] (Figure 5).

CCTV-Headquarters by OMA. The CCTV-Headquarters, an iconic OMA in Beijing, China (2012) for the China Central Television (CCTV), represents an alternative to the typology of the skyscraper, consisting of a 3-dimensional loop with a 75-metre cantilever [1]. To realize this geometry, a cantilevering steel-structure behind the building's skin was developed, which carries the whole building. One layer of the RBG visualization highlights that structure, whereas the other two layers show the internal core respectively the vertical communication and uses (Figure 6).

Seattle Central Library by OMA + LMN. The Central Library in Seattle, WA, United States (2004) represents a new type of library, "organized vertically against the traditional horizontal organization of traditional libraries" (Barba 2018). It consists of vertically stacked volumes and platforms, which are shifted against each other and define the geometry of the enclosing polygonal skin. The RGB visualization shows the external building skin, the interior space's relation between open and closed, as well as the structural components (Figure 7).

Beijing Olympic Stadium by Herzog & de Meuron. The "Bird's Nest" in Beijing, China (2008) is an iconic building, known for its visible structural network. The multi-layered lattice encases the building, but also facilitates an in-between space between interior and exterior. The structure consists of primary trusses, carrying the roof and the facade, braced by secondary elements (Brown 2009). The RGB visual-

ization reveals the well-organized primary structure system underlying the seemingly chaotic lattice (Figure 8).

BMW-World by Coop Himmelb(l)au. The BMW-World in Munich (2007), an event and delivery-center for BMW, is an iconic building, dominated by a double-curved, sculptural roof, hovering above a large open hall [8]. The roof, anchored by the double-cone, is constructed by a complex steel framework. The programmatic elements are located within the volume of the roof, as well as under it. By means of the RGB visualization technique, the roof panelization and the solar panels are shown, as well as the complex steel framework and the programmatic building volumes in and under the roof.

Centre Georges-Pompidou by Renzo Piano and Richard Rogers. The Centre Georges-Pompidou in Paris (1977) is included in the list of case studies for historical reasons, as an archetype of the 20th century that pioneered the use of actual colors to indicate different elements of circulation, such as air, electricity, water, escalators and lifts [6]. The RGB visualization highlights three components of the building, namely the structural system, the circulation of people and the ventilation concept.

London City Hall by Foster + Partners. The London City Hall (2002) is a glass building in the shape of a geometrically modified sphere [7]. The RGB visualization of this project takes a completely different approach than the previous ones. Here, the layers reveal, on the one hand, two construction stages, and on the other hand, the energy concept behind the form, explaining in a schematic way the relationship between the building's shape and its environmental performance.
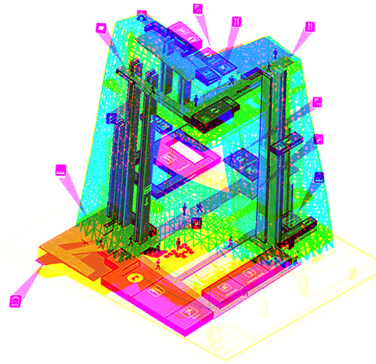

Figure 6
RGB visualization of the CCTV-Headquarters by OMA, showing an overlay of the structure of the building, the internal core , and the vertical communication and uses
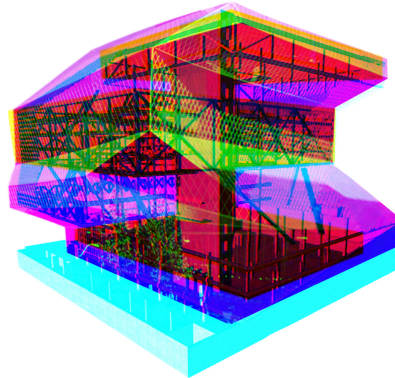

Figure 7
RGB visualization of the Seattle Central Library by OMA + LMN, showing an overlay of the structure of the building, the internal core , and the external building skin
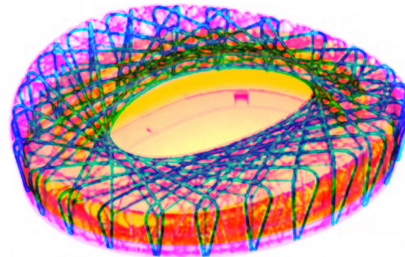

Figure 8
RGB visualization of the Beijing Olympic Stadium by Herzog & de Meuron, showing an overlay of the primary structure system, the secondary structural elements and the internal core

CONCLUSION

The project "anatomy of a building" introduces an analogue post-digital concept for educational, representational or artistic purposes. It investigates a new take on architecture visualization, appropriating concepts from other fields for architectural purposes. In this study, an interactive, playful approach is taken by using physical color lenses to highlight certain aspects of digitally-prepared multicolored images.

Color mapping is not new in architectural representation, as it can be used complementary to line, structure, form and detail, extending the visual vocabulary (Minah 2008). However, the visualization strategy presented in this study provides viewers with the new ability to select what they see in a drawing without the need of a computer to switch layers on and off.

In line with the post-digital tendency of revisiting old tools, this research merges digital and analogue media. Digital tools and well-known concepts such as layers are employed, but they are utilized in a new way, to actually formulate the compositional elements of an image. They are overlaid with the pre-digital physical-based interface of color lenses.

As it can be seen in the images presented in the case studies, the buildings are visualized in an unconventional way. In these superimpositions, new color patterns can be seen in the intricacy of the overlaid lines and fields. The images display an idiosyncratic aesthetic that draws the viewers' attention and curiosity. On the one hand, they visually represent the complexity of the selected projects, on the other hand, they allow for isolated views.

Future work aims to expand the current research to moving image and to create videos or interactive animations, where the user can alter color filters to visualize different information.

The authors will present a live demonstration of their case studies during eCAADe + SIGraDi 2019 Conference in Porto. The audience will be provided with colored lenses so that they can test the RGB visualizations and delve into the anatomy of buildings,

objects and urban plans.

IMAGE SOURCES

The RGB visualizations presented in this paper are compilations based on other images found on online platforms such as Pinterest, Google images, as well as books, magazines and social media. Some of the main sources of visual material are:

http: / /www.architectureweek.com /2006 /0111 /images_ /12913_image_2.jpg

https: / /es.wikiarquitectura.com /edificio /sede-de-la-cctv /

http: / /www.rasmusbronnum.dk /2009 /02 /21 /engineering-koolhaas-arup /

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[2] http://www.carnovsky.com/about.htm

[3] https://www.amazon.co.uk/Mysteries-Old-Peking-Chinese-Detective/dp/B00BPRPZU2

[4] http://www.archdaily.com/555694/fondation-louis-vuitton-gehry-partners/

[5] https://www.zaha-hadid.com/architecture/heydar-aliyev-centre/

[6] https://www.centrepompidou.fr/en/The-Centre-Pompidou/The-Building

[7] https://www.fosterandpartners.com/projects/city-hall/

[8] http://www.coop-himmelblau.at/architecture/projects/bmw-welt