

# Designing Media Architecture: Tools and Approaches for Addressing the Main Design Challenges

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Figure 1. Three cases of Media Architecture design for the public domain, in different contexts: (a.) Orkhêstra, (b.) HBK Media Façade, and (c.) Expo 2010.

## ABSTRACT

Media Architecture is reaching a level of maturity at which we can identify tools and approaches for addressing the main challenges for HCI practitioners working in this field. While previous influential contributions within Media Architecture have identified challenges for designers and offered case studies of specific approaches, here, we (1) provide guidance on how to tackle the domain-specific challenges of Media Architecture design – pertaining to the *interface, integration, content, context, process, prototyping, and evaluation* – on the basis of the development of numerous installations over the course of seven years, and thorough studies of related work, and (2) present five categories of tools and approaches – *software tools, projection, 3D models, hardware prototyping, and evaluation tools* – developed to address these challenges in practice, exemplified through six concrete examples from real-life cases.

## Author Keywords

Media Architecture, Media Façades, Design Tools, Design Process, Urban Computing.

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## ACM Classification Keywords

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## INTRODUCTION AND BACKGROUND

Although Media Architecture is a relatively new field, it has received much attention in the CHI community, to the extent that it is now maturing as a field of study and practice, with a dedicated ACM affiliated conference series [2, 3]. Early academic contributions to the field primarily offered case studies of specific installations [12, 13, 23, 26, 27]. As the number of Media Architecture installations has accrued, it has become possible to identify specific types of installations, for instance, the categorization of *performative, allotted, and responsive ambient* installations, identified by Hespanhol and Dalsgaard [17], recurring patterns of interactions, such as the *honeypot effect* [1], and the effect of spatial configurations on interaction [11]. Also, researchers have started to identify key challenges of designing Media Architecture installations. The most prominent example is that of Dalsgaard and Halskov [6], which outlines eight challenges pertaining to *novel interfaces, integration, robustness, content, stakeholder involvement, situational diversity, social transformations, and emergent use*, which have subsequently been expanded with three further challenges pertaining to *design process models, technical expertise, and evaluation* [29, 31]. As the specific challenges for designing in this field have become clear, recent research contributions have begun to examine tools and approaches tailored to address these challenges [15, 31]. However, an overview of these tools and approaches are lacking, and there has been no systematic integration of the tools and approaches with the identified challenges of designing Media Architecture.

In this paper, we combine insights from two leading research labs, The Center for Advanced Visualisation and Interaction (CAVI), Denmark, and the University of Munich (LMU) Mediainformatics Group, Germany, which, for the past seven years, have designed and carried out research in Media Architecture, including the development of 16 installations, to consolidate findings on the tools and approaches that practitioners can employ to address the challenges of designing Media Architecture. Our aim is to present and discuss how these tools and approaches – *software tools, projection, 3D visualization, hardware prototyping, and evaluation tools* – may be used in real-world Media Architecture design situations. Therefore, we exemplify this through six cases – *the Danish World Expo 2010 pavilion, Dynamically Transparent Windows, Odenplan, Olympic Village, Orkhêstra, and HBK Media Façade* – in which the tools and approaches have been employed, documented, and studied. Thus, the contribution of this paper is twofold: (1) *we provide an overview of tools and approaches for designing Media Architecture*; (2) *we discuss and exemplify how these tools and approaches may be employed to tackle the previously identified design challenges*. The cases and the tools are documented on the enclosed video.

The intended primary audience for this paper is the Media Architecture practitioner, who may employ or further develop the proposed tools and approaches. Furthermore, the presentation and categorization of the tools and approaches related to the challenges identified may be of interest as a reference and an overview for researchers.

The structure of this paper is as follows: We start by outlining the challenges identified in the existing literature on the field. We group these challenges into two overarching categories, pertaining to both the product and design process of Media Architecture. We offer this outline of challenges as a framework for presenting and discussing the main contribution of the paper, namely, five categories of tools and approaches for addressing the particular design challenges of Media Architecture. We then briefly introduce six cases of real-world Media Architecture projects, in which the tools and approaches have been employed and studied in practice. Then, we introduce the five categories of tools and approaches: *software tools, projection, 3D visualization, hardware prototyping, and evaluation tools*. We consider in which design situations they can address one or more of the challenges, and how they may be combined to address complex design problems. Finally, we discuss how these tools and approaches can help Media Architecture designers experiment with technologies, experience use situations, and test potential installations and systems.

#### CHALLENGES FOR MEDIA ARCHITECTURE DESIGN

Since our objective is to demonstrate and discuss tools and approaches that can help designers to address and overcome the specific challenges of designing Media Architecture, we

will first outline previous influential contributions regarding these challenges, drawn from the work of Dalsgaard and Halskov [6] and of Wiethoff [29, 31]. We divide the challenges identified in these contributions into two overarching categories, namely those pertaining to the *product* – Media Architecture systems– and those pertaining to the *process* – how to design, develop, and evaluate the systems. Our presentation of the challenges will be brief, since our main focus is on demonstrating and discussing tools and approaches, to address them in practice. We will refer to [6, 29, 31] for a more thorough examination of the challenges.

#### Product-related challenges

##### *Challenge 1: Novel interfaces*

As discussed by Halskov and Ebsen [15], many Media Architecture installations may be considered new types of interfaces with a variety of input and output configurations. Media Architecture installations extend into three-dimensional space, and may have a variety of shapes. In contrast to conventional displays with pixels organized in a matrix, there is not yet a standardized way of organizing pixels on media façades. Furthermore, the installations developed thus far employ a range of input technologies, spanning technology from camera tracking to SMS messaging.

##### *Challenge 2: Integration into physical structures and surroundings*

Media Architecture installations may be drastic interventions in the city and its architecture, which calls for concern for both the architecture of individual buildings, and also neighbouring structures, such as plazas and streets. Moreover, the design of Media Architecture needs to take into account the dominant viewing perspectives(s) of prospective users, as well as the spatial layout of interaction zones [6 (p. 2281)].

##### *Challenge 3: Robustness and Stability*

Compared to many other types of interactive installations, Media Architecture is typically more exposed to harsh weather conditions. Furthermore, installations in public places are often more exposed to vandalism and theft, and designers may need to adopt strategies for countering this, or alternatively, for overcoming and repairing installations.

##### *Challenge 4: Transforming social relations*

Media Architecture is often placed in public or semi-public settings in which people act in accordance with more or less established social relationships and interaction patterns. But the installations may disrupt and transform the existing social relationships, and create new ones. While this may have negative consequences, often, the specific purpose of an installation is to affect these patterns and relationships.

##### *Challenge 5: Emerging and unforeseen uses of places and systems*

Given the diversity of situations into which Media Architecture is introduced, it is likely to be perceived, used,

and in time, adopted by users in ways that were not anticipated. As knowledge about these systems and their use accumulates, it becomes easier to foresee how given spatial layouts and interface features are likely to result in certain types of use, as examined by Hespanhol and Dalsgaard [17].

**Challenge 6: New forms of content for a novel medium**

The unique characteristics of Media Architecture interfaces (see challenge 1), combined with the fact that these interfaces are integrated parts of the physical environment (see challenge 2) poses particular challenges, when it comes to developing content to suit the medium. The content has to fit the qualities of the display: scale, shape, pixel configuration, pixel shape, and light quality [15]. A key challenge concerning content is to support the communicative and interactive intentions of the media façade, while taking into account the situational circumstances [6].

**Process-Related Challenges**

**Challenge 7: Aligning stakeholders and balancing interests**

While exploring and negotiating stakeholder interests is a general challenge in the design of interactive systems, this becomes particularly complex when developing systems and installations that will be in the public or semi-public domain: a multitude of stakeholders, ranging from paying clients and local authorities to city residents and tourists, are likely to be affected by their introduction, and while some of them are likely to be partners in the design process, others may be end-users with little or no official say [6].

**Challenge 8: Diversity of situations**

Much Media Architecture is located in urban settings that host a variety of people and activities, often changing over the course of the day or week. A central design challenge is to uncover these patterns, and to develop systems that will respond appropriately. In many instances, Media Architecture will affect and potentially transform some of the existing patterns and social relationships [6].

**Challenge 9: Adopting design process models**

Since the field is novel and emerging, case studies of systematically designing Media Architecture from scratch have not yet been extensively reported [29]. Hence, practitioners face the challenge of adopting a systematic and structured design-process model involving architects, clients, stakeholders, and end-users.

**Challenge 10: Aggregating technical skills and expertise**

Media Architecture as the symbiosis of media and the built environment involves creating autonomous media systems with various interface solutions for (a) end-user participation and (b) system-relevant, back-end interfaces for exchanging content and adjusting settings. However, creating even early functional prototypes involving live models of Media Architecture is challenging, as this still demands very highly specialized technical expertise, for example, electrical engineering, coding experience apart

from knowledge of lighting design, architecture, urban planning [18].

**Challenge 11: Contextualizing and evaluating interaction**

Considerations of how to evaluate the end-product are challenges in every process stage of systematically designing Media Architecture. Because experience of Media Architecture differs from other forms of media involvement (e.g. laptops or personal mobile devices), as content is widely visible, consideration of the appropriate choice of evaluation instruments is essential [18, 29, 30].

To summarize, the challenges facing designers of Media Architecture are diverse, spanning technical, product-oriented issues and contextual, process-oriented ones. Consequently, a variety of tools and approaches are required to address them. Before we describe these tools and approaches, we will briefly introduce six Media Architecture cases, which we will use to exemplify the employment of the tools and approaches in practice.

**SIX MEDIA ARCHITECTURE INSTALLATIONS**

Since 2007, our two research labs have developed 16 Media Architecture installations in urban settings, in collaboration with stakeholders from the private and public sectors, including architects and technology providers. In this section, we present six cases representing the diversity of the field of Media Architecture, with respect to 1) scale, 2) setting, 3) technologies, 4) user groups, and 5) purpose. All the installations are shown in the accompanying video. We will briefly introduce these installations before discussing the repertoire of tools and approaches we applied in each case.

**Dynamically transparent windows**

The *Dynamically Transparent Windows* were part of the façade of a department store on a city high street [5]. The windows were fitted with thin strips of electro-chromatic foil that could change from opaque to transparent when an electric current ran through it. Enabled by camera tracking, the foil responded to the movements of passers-by, allowing them to see what was concealed behind the foil.

**Expo**

The façade of The Danish Pavilion at Expo 2010, designed by BIG Architects, was perforated with 3,600 holes of various sizes and configurations [15]. These holes were equipped with light fixtures hidden behind PVC tubes, diffusing light uniformly. The approximately 300-metre façade has a double-loop shape, and from some angles appears as two bands, one above the other (Figure 1c). In daylight, the façade displayed flickering white animations consisting of white surfaces broken by lines, fades, or silhouettes of people walking or bicycling along the façade. In the evening, animations included shimmering, abstract graphics, sweeps, fades, and animations along the entire length of the façade. Colours were mostly restricted to white and red.

### Odenplan

Odenplan is a projected metro station in Stockholm, Sweden. The building was designed by 3XN Architects for the Odenplan plaza in Vasastan, in the centre of Stockholm. For the exterior stairs of the metro, the proposal was to integrate bands of LEDs along each step. During the design process, three design concepts were created: *Contours*, *Playhead*, and *Traces* [20]. *Contours* emphasizes the contours of stairs by drawing lines along their edges, followed by each step being lit slowly upward, together with other simple visual effects. *Playhead* turns the stairs into a musical score sheet. Each step represents a stave, and the position of a person sitting on the stairs represents a note, which is played when a virtual playhead moves across the stairs. *Traces* creates visual traces of the people sitting or moving about on the stairs

### Olympic Village

For this project, one full façade of a bungalow in the Olympic Village in Munich, Germany, was equipped with a mobile and modular expandable media façade, including 1500 single LEDs. Three different interaction concepts were implemented, using different visual animations as proofs-of-concept for the prototyping tools provided: (1) an interface using bodily movements as input, (2) a tangible user interface, and (3) an interface using everyday objects as interaction triggers [18]. The different interfaces also triggered different visual content: the embodied interface showed large coloured bubbles according to the user's position, the tangible user interface empowered participants to paint their desired content on vinyl records provided, which would then be displayed on the façade. The third interface triggered a *digital fireworks* animation on the media façade, depending on users holding a lighting source (e.g. LED flashlight, smartphone camera LED, etc.) and pointing it towards the façade.

### HBK Façade

The project conducted at the Hochschule für Bildende Künste (HBK) [31] involved a large-scale, rear-projection media façade in the heart of Saarbrücken, Germany, and aimed to understand the distribution of *temporary ownership* among different users, with an interactive media façade. Therefore, the rear-projection media façade was furnished with a virtual game that participants had to play on the façade, using their mobile devices (Figure 1b).

### Orkhêstra

The large-scale media sculpture, *Orkhêstra*, [32] realized in the city centre of Frankfurt, Germany contained 4650 individual pixels (LEDs), and reacted to the flashlight of a smartphone or camera: when an image of the sculpture was taken, a virtual *sparkle* effect emerged, covering the whole sculpture. The goal of this project was (a) to understand the interplay between different construction materials, using only self-supporting laser cut elements, and (b) the interplay of disciplines involved in different phases of the design process of creating a new Media Architecture

installation involving a team of computer scientists, architects, and industry partners.

## TOOLS AND APPROACHES FOR DESIGNING MEDIA ARCHITECTURE

We now arrive at the core of the paper, namely, the repertoire of tools and approaches applied during the design of the six Media Architecture installations, and how these tools and approaches can be employed to address the specific challenges of designing media architecture. We present 13 different tools and approaches. Table 1 provides an overview of how these tools and approaches have been applied to address one or more of the 11 challenges.

	1. Novel interfaces	2. Integration	3. Robustness and stability	4. Transforming social relations	5. Emerging & unforeseen use	6. New forms of content	7. Aligning stakeholders	8. Diversity of situations	9. Design process models	10. Aggregating technical skills	11. Evaluation models
LightSet									*	*	*
Pixel tool	*					*				*	
Sketching on projections	*	*				*					
Full-size wall projection	*	*				*					
3D modelling	*	*				*					
Virtual video prototyping	*	*	*								
3D projection mapping	*	*				*					
Mockup		*	*								
Hardware prototyping						*				*	
LightBox	*		*							*	
Wire-LED-Mesh						*					
Urban Prototyping							*	*			*
Adopting User Exp. Methods											*

**Table 1. Overview of which challenges (top) have been addressed by which tools (left column).**

We organize the 13 different tools and approaches into five main categories: *Software Tools*, *Projection*, *3D Models*, *Hardware Prototyping*, and *Evaluation*. As we present each tool and approach in the following sections, we will also indicate how it addresses the identified challenges.

### 1. Software Tools

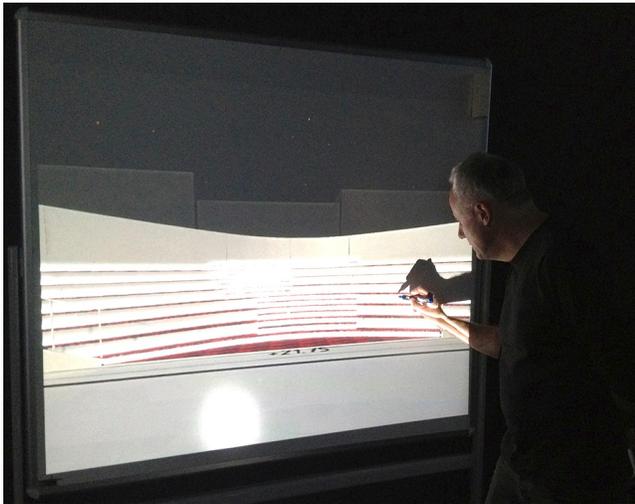
To lower the participation barrier and enable people to start prototyping, instead of fighting technical burdens, we implemented tools consisting of software components. Working with these tools allows one to *express* concepts physically, while supporting early end-user participation, and means for *in-progress* client presentations. We consider these tools approaches as ‘creative enablers’, since they empower smaller architectural practices to enter this novel domain, which in the past has been exclusively accessible to larger architectural studios that possess larger financial resources to overcome the aforementioned challenges.

#### LightSet

LightSet is a modular prototyping toolkit that supports the investigation of visual content for media façades in



developed tools to examine specific properties of a future installation.



**Figure 4. Sketching on projections.**

#### *Sketching on projections*

Designers in most Media Architecture projects will have access to 3D models, visualizations, or schematics of the future installation, or have the means to develop them themselves as part of the design process. A very rapid and low-cost way to make use of this type of visual material is to project it onto a whiteboard, and rapidly sketch with whiteboard markers, to explore the integration of the interface into the structure of the building, for instance (see Figure 4) (*re Challenge 1: Novel interfaces, and Challenge 2: Integration*). This method is well-suited to participatory events, for example, those involving a variety of stakeholders such as designers, urban planners, and local residents; first, because it requires no technical skills, second, because it makes clear to all parties that it is an open and exploratory approach (*re Challenge 7: Aligning stakeholders*).

In the Odenplan project, sketching on projections was used for rapid concept generation. The designers had a basic 3D model of the metro station and the surrounding area. A projector superimposed the 3D model on a whiteboard, and a second projection on an adjacent wall enabled designers to display and browse inspirational material for ideation and concept development. The participants in the concept-sketching phase could change both the inspirational sources in the background and the viewing angle and position of the 3D rendering of the model.

As a sketching approach, the benefits of projection are that it is cheap, easy, fast, and fairly easy for a wide range of participants to engage in. The drawbacks are that the output will typically need to be refined and transformed into other formats in the subsequent phases of the process. Some of this may be remedied through the use of smartboards, or wall-size, multi-touch surfaces, which may be intimidating for new participants in participatory events, however.

#### *Full-size projection on wall*

One of the prominent challenges of Media Architecture is related to the scale of the display, so, whereas software tools, such as the Pixel Tool discussed above, offer easy exploration and design of content while working at the desktop, this happens at the expense of scale (*re Challenge 1: Novel interfaces*). One way to overcome the limitation of the size of desktop computers is to project the display onto a wall, in order to explore content at full scale (1:1). In the *Expo Pavilion* case, the position of the projector was adjusted so the height of the projection corresponded to the actual height of the walls of the pavilion, enabling the designers to view content in relation to people walking in front of the imagery (*re Challenge 6: New content*). Working at full scale also enabled the designer to test content in relation people in the surroundings of the Media Architecture (*re Challenge 2: Integration*).

### **3. 3D visualization**

One of the significant challenges of designing Media Architecture concerns its integration into physical structures and surroundings that are fundamentally three-dimensional (*re Challenge 1: Novel interfaces, and Challenge 2: Integration*). 3D modelling tools such as 3DS Max and Maya are fundamental tools that may be employed as stand-alone tools or as platforms for more complex design tools and approaches such as virtual video prototyping and 3D projection mapping.

#### *3D modelling*

3D modelling and animation tools enable users to create digital, three-dimensional models of buildings and surroundings, for example, plazas and streets. Moreover, light sources integrated into physical structures may be visualized and animated, enabling designers to visualize the pixel configuration and experiment with interactive aspects of the Media Architecture (*re Challenge 1: Novel interfaces, and Challenge 2: Integration*). The 3D model is commonly created on a high-end PC, and visualized on a medium-sized display, but once created, the model may be shown on large displays, including 3D stereo displays, facilitating the investigation of the scale and form. Using 3D interaction devices, people can navigate through the model, and experience the Media Architecture installation from various visual angles, while moving around the building (*re Challenge 2: Integration*).

All three design concepts developed as proposals for the *Odenplan* metro, *Contours*, *Playhead*, and *Traces*, were visualized using 3D modelling and animation software. The visualization proved to be very powerful means of communicating how content and interaction may designed by integrating the technology into the physical structures and surroundings (*re Challenge 6: New content*). Furthermore, a 3D model enables the application of more sophisticated design methods, including *Virtual video prototyping* and *3D projection mapping*, see below.

*Virtual video prototyping*

Virtual video prototypes [16] are videos produced using virtual studio technology that makes it possible to combine videos of physical objects, including people, with video images generated in real time from digital 3D models (*re Challenge 1: Novel interfaces and Challenge 2: Integration*). Since virtual video prototypes also visualize people around media architecture the approach is particularly suited to addressing the potential for transforming social relations (*re Challenge 4: Transforming relations*). Moreover, virtual video prototype is a very concrete form of visualization, making it particularly suited to discussions with stakeholders (*re Challenge 7: Aligning stakeholders*).

For the design of *Dynamically Transparent Windows*, a prototype of a window with chromatic foil was created to test the technical aspects of the installation, and subsequently, the prototype was used as a physical object in the virtual studio, together with a 3D model of the façade of a department store and the city high street [5].

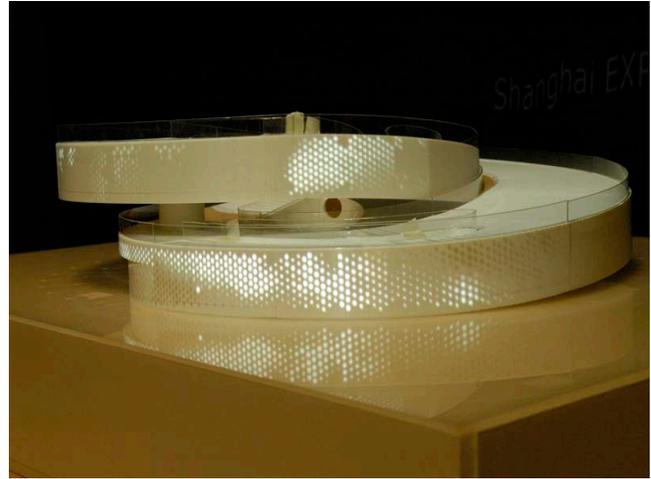
The virtual video prototype visualized the integration of the installation and the interaction as it might unfold in the context of the high street (*re Challenge 2: Integration*). One of the three *Odenplan* concepts was also visualized as a virtual video prototype, see Figure 5.



**Figure 5. Virtual video prototype of the Odenplan concept, Traces.**

*3D projection mapping*

Having a 3D model available, together with a physical scale model of the building, provides an exceptional opportunity to visualize the integration of a unique interface into the building (*re Challenge 1: Novel interfaces and Challenge 2: Integration*). *3D projection mapping* is based on having an accurate 3D model of the physical part of the installation [7, 10]. In the digital 3D world, we can produce digital content corresponding to the shape of a physical object, which may be subsequently projected onto the physical model of the installation, thereby augmenting the physical object



**Figure 6. 3D Projection Mapping on the Expo Pavilion scale model.**

One example of such a custom-made tool was a 1:100 scale physical model, onto which we were able to project the exact pixel configuration of the *Expo Pavilion* using three video projectors (Figure 6). Using virtual 3D technology, the model showed the holes as they would be illuminated on the pavilion and simulated the sunlight and cast shadows. This 3D Mixed Reality tool was based on technology recently developed by our research laboratory, in order to match physical objects with their virtual 3D counterparts, and thereby add visual content to precise locations on the object (*re Challenge 6: New content*) [6].

The physicality of the mixed reality model made for a valuable visualization for discussion among the members of the design team, and also made it possible to visualize the display in relation to the building in its totality, which turned out to be a powerful way to explain ideas to the collaborating architects. The main projector was mounted in the ceiling, and designers could walk around the table on which the model was placed, and share their views on the design. Based on the experience of collaborating with the architects, we argue that projection mapping is a powerful way to communicate Media Architecture concepts to stakeholders (*re Challenge 7: Aligning stakeholders*).

#### 4. Physical prototyping

Since Media Architecture often consists of innovative combinations of electronic component and other kinds of physical components, physical prototyping is a crucial design tool.

##### Mock-ups

*Mock-ups* [8] are low-tech design artefacts that simulate future products, and use physical materials such as cardboard, paper, wood, and slide projectors. Mock-ups are generally considered inexpensive to make, and easy to understand, experiment with, and modify. In architectural design, mock-ups are considered to have the advantage of representing actual size, and enable the evaluation of spatial configurations [15]. Media Architecture, mock-ups facilitate testing of the integration of the interface into the built structure (*re Challenge 2: Integration*).

Halskov and Ebsen report on how, in the early phases of the *Expo Pavilion* case, the designers created a full-scale mock-up of a section of the building, in order to experiment with how to turn the holes in the façade into pixels by mounting light fixtures behind PVC tubes [15]. A number of experiments led to a conclusion with respect to which combination of light fixtures and PVC tubes produced the most uniform light distribution. Moreover, the mock-up revealed that the shape of the individual pixels depended on the viewing angle. In the case of the *Expo Pavilion*, the mock-up was crucial for the investigation of the novel interface at the pixel level (*re Challenge 1: Novel interfaces*), but also to address stability and robustness issues with respect to the integration of the individual light sources into the physical structure of the building (*re Challenge 3: Robustness*).

In the HBK Media Façade project [31], content and interfaces were pre-tested before a final implementation on a true-to-scale mock-up, a 1:100 miniature version of the whole building, including the façade, emulating the display of media by using small-scale data projectors.

##### Hardware Prototyping

Using off-the-shelf hardware components [18, 19] to build early versions of interactive prototypes is a quick way to express initial design concepts and get user feedback. Owing to the broad distribution of communities around open-source hard- and software platforms, this practice has gained widespread acceptance. Additionally, large LED manufacturers release modular hardware bundles that are relatively easy to access and transform into early versions of design proposals (*re Challenge 6: New content*).

Since the development of any content for a new medium is challenging in many ways, especially when dealing with low resolution displays, standard visuals such as fonts or images might not be visible to observers, and pre-testing content, components, and interactivity is crucial. Furthermore, by applying easy-to-use hardware prototyping tools in the design process, the challenge of aggregating

technical skills and expertise (*re Challenge 10: Aggregating skills*) cannot be completely overcome; however, the entry barrier may be lowered.

##### LightBox

Assembling hardware to test and investigate robustness and stability (*re Challenge 3: Robustness*) is a good way to pre-test software on the actual components before final implementation. Additionally, working with early hardware prototypes may serve as a brainstorming method to test and envision possible interaction concepts, and experiment with animations and visual content (*re Challenge 6: New content*). This is especially crucial when low-resolution media façades are involved, as the resolution of these façade types may not support the display of images or text (*re Challenge 1: Novel interfaces*).

In this vein, Wiethoff and Bloeckner created LightBox [28], a miniature lighting lab to explore content proposals before a subsequent implementation, which works with the actual (hardware) components in a simple and easy way, making hardware prototyping accessible to people with limited technical skill sets (*re Challenge 10: Aggregating skills*).

Besides using LightBox as a brainstorming tool, robustness and stability, responsiveness and lighting effects could also be simulated and visualized before working on the actual media façade.



**Figure 7. The hardware prototyping toolkit LightBox, for exploring content for low-resolution Media Architecture before the final implementation [28].**

Lightbox was utilized for a project involving a novel interaction mechanism to control media façades [29]. Here, the hardware prototyping tool served as a medium to explore content and interactivity before it was transferred to the actual façade, which allowed more design iterations.

##### Wire-LED-Mesh

For the Orkhêstra project, we utilized a bendable LED Mesh. We needed a prototyping medium that was highly mobile and deformable, while still retaining a specific shape [18, 32], in order to quickly model initial shapes as

low-fidelity models of the end-product. Here, LED lighting elements were attached to the Wire-LED-mesh in order to work with the actual hardware.

Addressing the challenge of developing content for a new medium (*re Challenge 6: New content*) we referred to the Wire-LED-Mesh as, owing to its materiality, as it may be deformed and still maintain its shape, a characteristic that is very valuable when prototyping non-planar shapes with low fidelities, while simultaneously testing content, as in the case of the aforementioned projects.

### 5. Evaluation approaches

Investigating experiences with Media Architecture is important, as it provides cues for the designers and architects involved, regarding whether or not their envisioned concept has a chance of being accepted. The metrics in question should highlight and cover the experience people will encounter when they interact, or exchange data. Hence, a good evaluation is to utilize methods that are also feasible during varying conditions, such as (a) Dynamic Environments: evaluation tools need to work with live, shifting audiences, and large numbers of users; (b) Limited Time: in public settings, the time for users to explore a prototype and participate in additional questionnaires/interviews is often limited, as people wish to *move on*; (c) Multiple Users: evaluation tools need to consider that projects also involve many people interacting simultaneously with a prototype; (d) Goal of the Interaction: sometimes, the reason for users to interact with a new system is not to test one specific function, but instead, to experience the interaction with the Media Architecture itself, a matter that separates the choice of evaluation tools from the domain of task-oriented, experimental, HCI study designs.

If the built environment becomes an interface, clearly, the appropriate evaluation format should match the desired goals of the interaction. Based on previous experience, two types of evaluation tools have proven to be more successful than other approaches: urban prototyping, and adapting user experience evaluation methods.

#### Urban Prototyping

Conducting user studies ‘in the wild’ [21], or directly involving the residents of a city district is a method for inspecting user experiences and reactions in situ [18]. One recently established workshop-like format to involve local residents in their environment and confront them directly with new solutions was exemplified by the *Urban Prototyping* movement developed in San Francisco 2012 (Figure 8). Here, residents gained local access to initial prototypes, and were able to explore installations by themselves, before a concept reached a more mature stage, in terms of technical development.

Using the foregoing approach in the context of the *Olympic Village* project, we were able to (a) show initial interaction concepts to potential users before a possible

implementation, and (b) judge their acceptance. Additionally, a structured workshop format was applied, in which practical tasks were given to participants, and valuable insights captured [18].



**Figure 8. Urban Prototyping as an evaluation approach for designing Media Architecture in conjunction with residents [18].**

#### Adopting User Experience (UX) Methods

In the context of a project conducted in conjunction with the German Research Center for Artificial Intelligence, Saarbrücken, Germany and the ARS Electronica Center in Linz, Austria [29], we investigated appropriate ways of evaluating user experiences’ while interacting with Media Architecture in front of large audiences. To more holistically capture the users’ experiences and emotions in this context, we adopted user experience (UX) evaluation methods to suit our context. For example, the valence marker method initially presented by Burmester et al. [4] was adopted suit our study design: in the project setting, participants had to record *valence markers* for positive or negative emotions. In a subsequent laddering interview [25] questions directly addressed these markers and statements, later categorized according to a UX-based evaluation scale, to more holistically understand behaviour in this context, and served as a starting point for further investigations [30].

#### DISCUSSION

Over the course of this work we have shared how we have addressed previously identified design challenges for Media Architecture design by applying a repertoire of design tools and approaches. The impact and the systematic design of using digital technology wisely in different architectural contexts to archive a robust, useful, and enjoyable outcome remains still challenging.

If we revisit Table 1, which offers an overview of how the tools can be employed to address the identified challenges,

it is clear that some challenges have been addressed more intensively than others. Some of the challenges, *Challenge 1: Novel Interfaces*, *Challenge 2: Integration into physical structures and surroundings*, and *Challenge 6: Developing content to suit a new medium*, have been addressed by several of the tools and approaches. This suggests two things: first, that the current set of tools and approaches may go at least some way in terms of supporting designers of future Media Architecture projects; second, that the main efforts of these early years of Media Architecture have focused on technical and product-oriented aspects. This hypothesis is supported by the fact the *Challenge 4: Transforming social relations* has only been addressed by a single tool and approach (Virtual Video Prototyping), and that none of the tools and approaches have been successfully employed to address *Challenge 5: Emerging and Unforeseen Use*, and *Challenge 8: Diversity of Situations*. Our experience from some of our projects suggests that the collection of tools may be profitably supplemented by conventional design methods. For instance, we applied the Inspiration Card Workshops method [14] to address *Challenge 5: Emerging and Unforeseen Use*, by bringing inspiration from other successful cases that enabled emergent use. Another example is the Bthere method [9], which is a method aimed at increasing the context awareness of design, and may be applied to address *Challenge 8: Diversity of Situations*.

A key part of competence in design is mastering the tools of the trade. These may vary greatly from field to field. Typically, the most used tools in a field are generic and adaptable, so they may be both employed across a range of projects, and be fitted to the specific practices and preferences of individual designers. Examples of such tools range from pen and paper for sketching, to graphics software such as Photoshop. However, few tools are born generic and adaptable. Typically, tools are developed to solve a particular problem, and then subsequently – provided that they are usable and successful for the specific task – refined and further developed for a wider set of problems. While some of the tools and approaches for Media Architecture listed here are relatively generic – for example, 3D Modelling and Sketching on Projections – each of them has been developed for specific purposes. Much work remains to be done, if they are to be transformed into more generic tools for the field. As Table 1 indicates, there are also acknowledged challenges for which we have yet to develop suitable tools and approaches.

To make the systematic design processes of new projects more structured, we provide case studies, supplemented by tools and approaches, in order to provide others with potential starting points. Towards the goal of a complete overarching set of tools and methods for all the individual challenges outlined in the first section of the paper we provide in this work (a) the first confrontation of tools, approaches and challenges dedicated to the Media

Architecture practitioner and thereby (b) share individual approaches to address these challenges to develop Media Architecture more systematically in an emerging and rapidly changing context.

## CONCLUSIONS

In this paper, we have provided guidance on how to tackle the domain-specific challenges of Media Architecture design pertaining to *interfaces*, *integration*, *content*, *context*, *process*, *prototyping*, and *evaluation*. To overcome and solve them requires an interdisciplinary discourse, and collaboration spanning many fields. Therefore, future research in this domain is essential for the successful development of Media Architecture. Without the holistic understanding that such work will deliver, conventional Media Architecture deployments will probably fail to meet the aspirations and expectations of private and public stakeholders [22].

As every design situation and context is unique, the transferability of these tools and approaches to other projects demands careful consideration by the designers involved. In most cases, it will be necessary to alter the tools and approaches to fit the circumstances of the design situation. While this is true of tools and approaches in many areas of interaction design, it is particularly pertinent to Media Architecture, since most of the tools and approaches have been developed to suit specific problems, and have not yet been developed to function as generic tools.

**To summarize**, there is both an unprecedented opportunity and an urgent need for knowledge sharing regarding how the challenges of designing Media Architecture may be systematically addressed to support and accelerate the further development of this emerging domain.

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