A Media Architecture Approach for Designing the Next Generation of Urban Interfaces

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Abstract. The augmentation of the built and urban environment with digital media has evolved and matured over recent years. Cities are seeing a rapid rise of various technologies; a trend also accelerated by global crises. Consequently, new urban interfaces are emerging that integrate next-generation technologies, such as sustainable interface materials and urban robotic systems. However, their development is primarily driven by technological concerns, leaving behind social, aesthetic, and spatial considerations. By analyzing our own media architecture research projects and real-world applications from the past two decades, we offer a structural approach for developing these new urban interfaces. The individual cases provide early insights and challenges related to prototyping and augmenting contexts with novel input and output modalities. These results in common, preliminary observed patterns in the process of integrating next-generation technologies into urban environments and surroundings, in response to continuously evolving social needs.

Keywords: HCI, Media Architecture, Prototyping, Robotics, Interaction Design.

1 Introduction

Following previous developments of media architecture in retrospective, such as the initial fusion of physical and digital architectural interventions [20] and, later, media façades or large urban displays [13], the field has expanded and matured. The integration of digital media into the architectural form of the built urban environment is no longer limited to lighting technologies for transforming buildings at night. New forms of applications are emerging that integrate novel technologies within urban contexts. Here, we can observe specific technological trends in augmenting cities. For example, virtual reality (VR) and augmented reality (AR) were implemented as urban interfaces via wearable or mobile devices (VR/AR) [48]. These technological aides provide citizens with additional information on their urban surroundings [53] and, in turn, can lead to behavior changes [57].

Fig. 1. Examples of new autonomous systems entering urban spaces: the commercial robot *Spot* by Boston Dynamics (left), Amazons *Prime* delivery robot (middle) and the *Urban Rivers Trash Robot* in Chicago (right). ©Web Summit, ©Kldalley6, and ©UrbanRiv.org CC-BY-NC-ND 3.0

Further, the utilization of robotics (see Figure1) within urban environments spread awareness among the research community on novel and feasible ways of creating media architectural interfaces in the public domain. These works pave the pathway towards a new understanding of the term *media architecture* and its application areas. They encapsulate *digital media* in novel forms and expressions, for example, using movable robotic elements equipped with LEDs, feedback via locomotion or audio channels, and embedded haptic interfaces, to name a few examples. Given their significant departure from the traditional media façades and urban screens, these developments point to a new generation of urban interfaces that manifest a paradigm shift in the field of media architecture. At the time of writing this article, a pandemic is striking the planet and raising new issues, especially in highly populated and dense areas. Many countries have deployed mobile virus warn apps tracing transmissions that inform citizens if they have recently been exposed to the risk of infecting infection (see Figure 2, right). This new demand for civic information accelerates the public space's reorganization as long believed traditions and urban rituals seem now invalid since they do not comply with international hygienic standards. Simultaneously, city officials are reacting to citizens' demands using the urban infrastructure and space differently: pop-up bicycle lanes and flagged out areas for public gatherings have been common ad-hoc responses to deal with the sudden challenges brought by the pandemic (see Figure 2, left). Further, we can see an acceleration in deploying robotic technologies in cities, with governments granting permission to deliver robots on sidewalks [44] and robots enforcing social distancing rules [43]. Thus, the often-predicted transition of robots from factories into public, urban spaces is no longer a near-future scenario [39]. It is happening right now, with many cities becoming living labs for these developments [60]. However, such rapid transformation can also lead to new dilemmas concerning the widely discussed replacement of the human workforce and the disruption of the urban space and its underlying complex social construct. We further begin to see the infiltration of AI-enabled non-human entities and stakeholders [36].

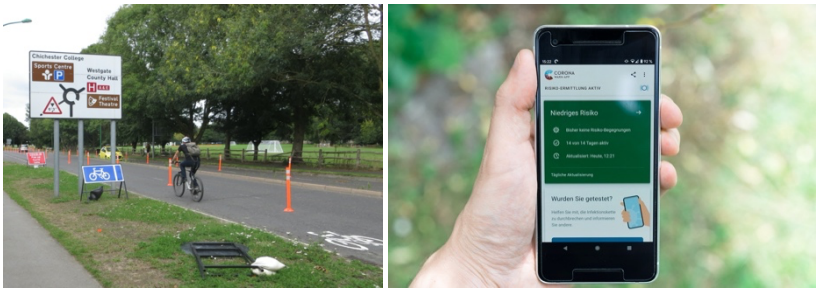

Fig. 2. Pop-up bicycle lanes in the U.K. (left) and a user interacting with a mobile virus warn app (right) as a direct consequence of an immediately changed behavior due to a pandemic. ©Djm-leighpark and ©Markus Winkler, CC-BY-NC-ND 3.0

As an interdisciplinary field and community of practice consolidating Interaction Design (IxD), Architecture, Human-Computer Interaction (HCI), and practice-led urban prototyping [30], media architecture has long been dedicated to the responsible integration of new technologies and digital media into cities. Hence, in light of these new challenges, we argue that media architecture can and should provide a solid foundation of lessons learned and methodological insights offering guidance in asking the *right* questions and delivering responses to this radical shift. We believe that a deeper reflection on each field's role individually and concerning the other areas can provide directions on creating meaningful dialogues between people, the built environment, and emerging technological entities living in changed urban realities. Although the changes initiated through these particular circumstances might be temporary, similar rapidly shifting crises at the city, regional or global level are regularly emerging, such as, for example, displacement caused by natural disasters, social upheaval, climate change, and the global refugee crisis. Based on that, we posit that the need to react to novel global challenges quickly will be a persisting phenomenon for the next decades, demanding technological means and prototyping strategies to respond and ensure urban resilience adequately.

In this article, we provide a holistic reflection on the transition of media architecture towards integrating new technologies, such as robotics and AI, creating new forms of interfaces, which we refer to as *next-generation urban interfaces*. The article builds on and extends previous work, which, over time, have developed from the form of flat screens [39] to media façades and media architectural installations [59]. Such urban interfaces allow situated access to information and enable citizens to participate in the co-creation of their urban experience [58]. The adoption of new technologies in a city context enables us to imagine new urban interfaces beyond flat screens and media façades, for example, allowing for the interactions between citizens and urban robots [27]. The article discusses our recent experiences from different cases prototyping and pre-testing possible indicators for next-generation urban interfaces and investigating the role of HCI in this new urban reality. As we are confronted with novel design challenges, the question persists on how these can be addressed and linked to current design demands, such as designing an eco-friendly built environment and urban lighting overuse (see Figure 3). The abovementioned paradigm shift within media

Fig. 3. Example of an eco-friendly architectural design in Milan (left) and lighting pollution in Hong Kong (right). ©Plflcn and ©Przemek Jaczewski, CC-BY-NC-ND 3.0

architecture also often includes new types of ubiquitous design materials distinguished from previous standard choices such as LEDs, large urban displays and projections, as the manifestation of digital media is no longer limited to stationary and fixed positions [27]. We believe that a research-through-design approach [68] is suitable to address the challenges mentioned above. It accelerates the creation of insights and knowledge on user acceptance in this emerging domain [68].
In this article, we address the following research questions:

1. Are the previously identified processes and challenges for successfully integrating media architecture into the city still relevant in light of the novel frontiers that this domain is heading towards?
2. What new challenges can we identify from the analysis of recent case studies and reference literature?
3. How can those challenges be systematically addressed through different prototyping techniques in conjunction with the intended user groups?

To answer those questions, we present as case studies three projects we have recently developed. We present them in the form of an 'annotated portfolio' [6], a format widely adapted by the design research community to present a collection of designs and construct intermediate-level knowledge [33], which lies between particular design instances and more generalizable knowledge. In doing so, our cases shed light on the emerging concerns in the media architecture domain. We exemplify how next-generation urban interfaces could be crafted to tailor architecture and computers' behavior to fit emerging human needs. Our contribution lies in synthesizing the presented cases, providing a reference for urban practitioners and researchers. We consider these as *building blocks* for systematically tackling domain-specific challenges derived and expanded from those previously identified in the literature [14]. In the wake of new social and spatial constraints brought by the novel suite of technologies employed. In summary, we provide four main contributions:

- An account of the transition of the research domain *media architecture* towards the sustainable integration of emerging technologies such as robotics and AI.
- An examination of new challenges for the next generation of *media architecture*, brought by this transition.

- Case studies that provide insights on prototyping processes and methods addressing the previously described challenges.
- A reflection of the presented cases in light of this new frontier.

2 Past, Present and Future of Media Architecture

Widespread architectural illumination has become economically viable through the electrification of cities and can be considered a precursor of today's media architecture [41]. In particular, the rapid development of light-emitting diode (LED) technology has significantly contributed to its present form and aesthetics. Consequently, architects began to use digital media as a dynamic building material [63], which turns buildings into prestigious landmarks that attract people and contribute to activating night-time economies. With media façades becoming a global phenomenon in the past decade [22], researchers and practitioners of various backgrounds investigated the opportunities of this new medium in a collective effort and accompanying challenges and risks. For example, architects were mainly concerned with displaying display technologies' spatial and aesthetic integration into architectural structures. Therefore, spatial, low-resolution media façades gained popularity, as the digital content would not compete with the architectural form but rather transform into an integral part of it (see Figure 4, bottom left) [65].

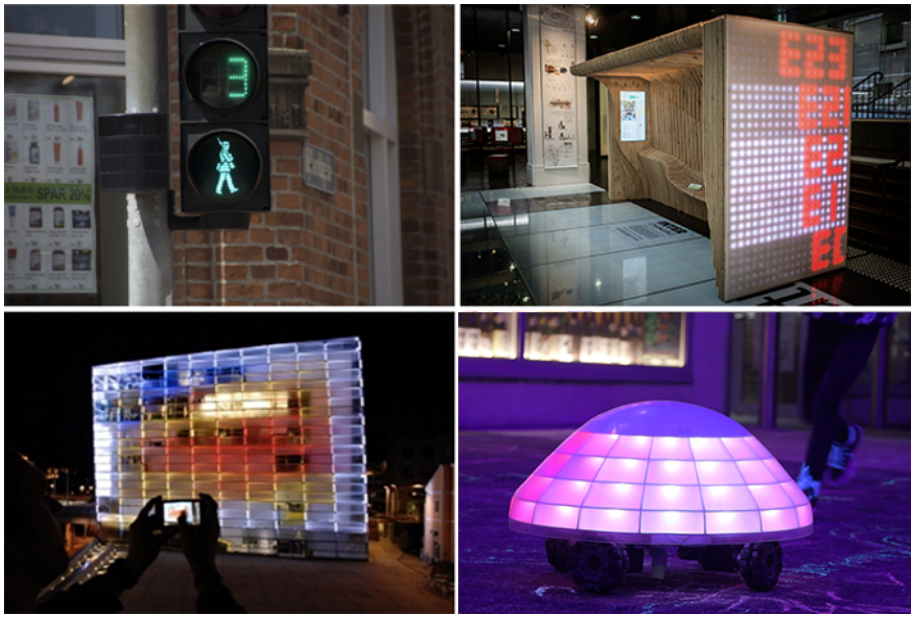

Fig. 4. Examples of urban interfaces in various application contexts to illustrate an increasing complexity: from simple traffic lights (top left), to mediated city infrastructure (top right), large-scale media facades (bottom left), and robotic urban displays (bottom right).

In this vein, HCI researchers investigated the information capacity of low-resolution media façades [47], for example, to visualize urban data [46], and developed suitable interaction techniques. Bridging the gap between people and buildings, they investigated the use of mobile devices [61] or gesture-based embodied interfaces [24]. Often these developments have been carried out following rapid prototyping [30], and do-it-yourself (DIY) media architecture approaches [9], which allowed quick testing and evaluation of design concepts with potential users in different environments. In one of our previous case studies, we deployed an ambient low-resolution lighting display integrated into a bus stop prototype. The aim was to envision a future public transport hub in a public plaza to investigate the aesthetic integration of public transport information (see Figure 4) [21]. In another study, we deployed a mechanical flip-dot display at the front yard of two residential houses to display private energy consumption, making a case for media architecture and its communicative and informative role on a hyper-local scale [32].

Following an action-oriented research approach [17], insights from those research studies often led to design recommendations targeting a particular context and technology use. However, with the consolidation of media architecture as a mature field over the years, researchers also began to synthesize their findings into a more generalizable and formalized set of guidelines and approaches. Building on an extensive repertoire of cases and long-term experience in the field, Dalsgaard et al. identified an initial set of challenges in designing media architecture interfaces [13]. Later, they revised those challenges and categorized them into product-related challenges, e.g., the seamless integration of digital media into existing physical structures and process-related challenges of such systems' design and development process [14]. One of these process-related challenges is the aggregation of technical skills and the demand for highly specialized expertise, such as coding and electrical engineering, beyond the skill set of traditionally trained architects. In response to this challenge, one research contribution in the past has been developing prototyping tools to lower the technical hurdle of designing and evaluating (interactive) content for media façades [31]. Another challenge identified by Dalsgaard et al. [14] relates to adopting existing design process models. More broadly, media architecture and urban interface design are confronted with a broader range of stakeholders than the traditional user interface and product design. While these directions established human-centered design approaches and methodologies (e.g., participatory design) to collect end-users' opinions, media architecture needed to develop their approaches and methods. For example, Tomitsch [55] highlighted the issue that customers of smart city technologies (e.g. governments, building owners) are not necessarily the end-users of the system and that designers deploying technologies in public spaces also have to give voice to the "non-users" [53]. As reported by Vande Moere et al., based on an analysis of real-world cases of media architecture [58], not considering these stakeholder groups and ignoring the socio-technical context can lead to denial by the local community or even vandalism. Researchers have systematically investigated approaches to overcome this challenge to evaluate urban interfaces before the final deployment and include citizens in the design process as active co-creators. Hoggenmueller and Wiethoff [30] and Korsgard et al. [34] described how they used

lightweight and temporal urban prototypes in a bottom-up approach to elicit in-situ feedback from citizens and to enable a critical discussion around urban technologies. Fredericks et al. presented a middle-out engagement model in this vein, including decision-makers and local communities in the city-making process [19]. Based on research studies across media architecture and smart cities, Tomitsch [55] proposed a design process model that translates established interaction design practices into the urban environment. The model comprises the stages of understanding, designing, building, and deploying. Each of the steps includes methods for engaging users and other stakeholders. This review demonstrates that media architecture has developed over the years from a field with a singular and product-centric focus on media façades towards offering a plethora of methods and structural approaches. However, to design human-centric urban technologies, it is also apparent that the field has to respond to new challenges. These include challenges arising from the deployment of new urban technologies, such as robotics and AI systems, going beyond the capabilities of established forms of digital urban media and smart city applications coming with new degree levels of agency (see Figures 1 and 4) [11]. Further, there is now increasing awareness in the community towards more sustainable urban technologies [29]. This is related to the contradiction inherent to current smart city approaches: while, on the one hand, they promise a more sustainable form of living (for example, by conveying educational messages or promoting behavior change through media architecture interventions [54]), on the other hand, they rely on technologies which often have themselves a negative impact on the environment (for example, causing light pollution [67] (– see as depicted in Figure 3 on the, right) – [67] or contributing to electronic waste [25]). To deal with this dichotomy, researchers have begun to consider more sustainable interactive materials [4] and applying more-than-human centred approaches in media architecture to consider the greater ecological system [18]. In the following sections, we provide a closer look at these novel challenges, focusing on the aspect of prototyping for these new landscapes in media architecture.

2.1 New Challenges - Prototyping Sustainable Interaction Design

Ecological design is a trend that is a response in architecture to the globally increasing ecological challenges. The term is associated with the sustainable design paradigm in HCI. The differences between these fields, however, reflect their orientation and their key issues. They reveal a gap between two parallel developments: In the context of architecture, ecological design describes an overall concept aiming to create a sustainable built environment that promotes human psychological and physical well-being [1] on very various levels. Other projects exemplified equal attempts to integrate climate-neutral maintenance processes or energy supplies, including the usage of local materials and self-supplying systems [9]. In these examples, sustainability is focusing on reducing polluting factors by reusing or recycling existing materials. However, the increasing population density and the growing technology usage in urban areas require changes also on a more holistic, social, and societal level [10]. Sustainability concepts are applied to the story of a bigger (eco-) system, repurposing also cultural and social norms and conditions.

These circumstances create an opportunity for new media architecture interfaces that support a calmer, aesthetic, and recreational atmosphere and which invite community-building activities. Current strategies in this direction use, for example, include plant or mobile interfaces [16]. Recent HCI research includes research on sustainable materials and focuses on creating awareness and communicating climate conditions transparently to a public audience. Related projects include wearables indicating the level of noise pollution [51], frameworks for sustainable prototyping approaches [35], or the development of *modern technology* interfaces supporting a more sustainable lifestyle. For example, in the sense of reuse, Robinson et al. augmented a mobile display by implementing a robot to draw pictures in real size on a table surface with food resources, such as lentils or salt [50]. The project targeted users from developing countries, where technological devices, except phones, are still scarce. We consider this a prominent example for an HCI research project finding a solution for societal and economic problems by using reusable, sustainable resources. The commonality of these research projects shows their concerns using augmented materials, structures, and resources. Each domain develops strategies for maintenance, reuse, well-being, and so on. However, each also emphasizes different perspectives.

The focus seems to be either on a very detailed level of biochemical possibilities for material research and pollution regulation or on a holistic urban design perspective in architectural design. Instead, HCI researchers were have been concerned with technological solutions that supporting implicitly or explicitly behavior changes. In summary, these approaches were targeting a more sustainable lifestyle of the individual and groups. Aiming to tackle these new challenges for media architecture, we suggest a cross-disciplinary approach that supports a sustainable built environment and a transparent interaction design for humans by creating awareness and triggering sustainable behavior changes. In our research, we aim to enable cross-collaboration and extended skill-sets. But we yet have to investigate which methods and tools can be adapted to the new challenges the media architecture domain is currently and increasingly confronted with through current circumstances.

2.1 New Challenges - Prototyping Interaction Design for Urban Robots

Over the last decades, automation in architecture has become a widespread standard. Approaches to face the previously described ecological challenges include modern façades regulating the inner climate by providing shade when needed or filling a space with sunlight during cold winter days. I.e., the now-iconic residential towers at *One Central Park* in Sydney, Australia, completed by the French architect Jean Nouvel in 2014, are covered in terraced vegetation and equipped with a motorized heliostat cantilevering from one of the towers. The system reflects sunlight down into the shared park area, overshadowed by it [45]. We argue that today's architecture is as much about intelligent control systems and robotic infrastructure as it is about raw materials and construction. Non-graspable factors such as the weather, the daytime, or even group dynamics influence a building's inner processes. Hence, people are currently implicitly interacting with intelligent buildings and robotic façades. However, today and even more so shortly, the robotic architecture will spill over in areas and spaces of daily use and direct user contact (see Figure 1). Thus, the

interaction with these systems becomes explicit and individual. Examples range from architectural art to urban robotic systems. Especially in public urban spaces, modern city infrastructure is currently on the verge of automation: nowadays, autonomous systems increasingly operate public transport. This changes the way people behave in situations like road crossings since inter-human communication, such as eye contact with the driver of an approaching vehicle, is no longer applicable. Instead, the question persists on how citizens interact and understand such (semi-)intelligent entities in the urban environment. In the past, strategies focused on improved communication [37] or creating awareness of the system status [49] to provide pedestrian safety. However, urban robots' interaction design remains a major challenge of current research in the urban environment and needs to be investigated over different contexts, cultures, and technologies. In the long run, these developments include the possibility to change the face of cities permanently. Urban planning and development could move far beyond classical urban design since there would no longer be a need to separate urban technology and citizens. Both technologies and humans will be intelligent entities acting and reacting in the same shared urban space, requiring the development of shared space concepts [23]. Yet, the question persists, how to design interaction for such future scenarios? How do we approach prototyping urban robots? What can we learn from media architecture practices to define prototyping approaches for urban robots?

3 Cases

As previously mentioned, both fields, architecture, and HCI discuss sustainability in the context of reusable and repurposed materials and (eco-)systems. Both deal with socio-spatial relationships' changes under the increasing deployment of AI and robotics in public places. We share our preliminary investigations of these aspects with the following case studies. In the first case study, we introduce an example of how interaction design can support sustaining existing structures and materials in architecture. The subsequent two case studies discuss how interaction with robots challenges the current design conditions.

3.1 Traces-of-Use: A Design Metaphor for Sustainable, Non-Light Emitting Urban Interfaces

In this case study, we address the challenge of embedding interfaces in the built environment by exploring the augmentation of existing materials and structures. This on-going study aims to develop a recognizable interface design that embeds itself smoothly by reusing patterns and characteristics of previous human traces. One of the challenges is to guide and manage the user perception, understanding, and expectation, as we plan to turn existing, non-interactive surfaces into interactive ones.

We presented the novel idea [26] of applying *traces-of-use-inspired* interfaces in urban environments. This design concept's metaphor was chosen as urban traces captivate due to their ubiquity, recognizability, and simplicity. Our design approach

aims at augmenting the built environment with calm technologies. Furthermore, our work includes creating a universal design language for input modalities based on

Fig. 5. Example of a human traces of use at a playground shown through colour differences (left) and UI elements inspired by this metaphor (right) realized using concrete, each in an abstract (top row) and in a used version (bottom row).

repurposing familiar patterns. Figure 5 (left) shows an example of such traces of a publicly accessible playground object. The current interaction with smart buildings or other public environments is mainly conducted through an additional device, such as mobile phones [5] or pervasive displays [9]. However, a direct interaction technique could be more engaging and facilitating behavior changes towards an increased social interaction and self-identification with the surroundings [66]. This potentially enables possibilities for embodied interaction with modern technologies *in context*. Another argument to further investigate calm interfaces is the increasing number of media façades and society's increasing mobility, requiring many attention capacities and causes lighting pollution [66]. Consequences affect the human's psychological well-being and the surrounding ecosystem negatively [18] (see Figure 3, right). Augmenting urban environments with these issues in mind, we acknowledge an immediate need to find an appropriate balance between obvious (explicit) and implicit augmentations.

In our ongoing work, we tested the combination of using concrete as interface material for input control elements with the *traces-of-use* inspired design strategy. As the first step, we decided to prototype three control elements, a slider, a button, and a scroll wheel. We agreed on these elements, as they are well-known metaphoric representations of interaction control elements. Transferring *traces-of-use* properties in the prototypes, we created two versions of each component (see Figure 5, right). Conducting early studies, we summarized that the worn-looking shapes invited participants to explore and to engage. Signs of previous human interaction seemed to encourage people. The abstract design provided the chosen affordance because the elements' shapes were more related to what participants already knew and familiar to their mental model of a slider, a button, or a scroll wheel. Reusing materials from one environment, in our case concrete, requires to change the users' mental model from a non-interactive to an interactive paradigm. In comparison to current media

architecture, concrete interfaces hold rather implicit visual indications. In summary, we acknowledge that a balance between perception and usage of new affordances in the built environment is relative to the context. Further aspects that influence the behavior with new types of non-light emitting urban interfaces include the purpose of use, the influence, meaning of the location, and the user group's cultural background.

Research questions arise on (1) how to approach, trigger, and maintain these changes to enable sustainable reuse of the environment for interaction? We further question (2) how to bridge different media architecture generations with dynamic development in society and technology? Lastly, the topic introduces the discussion about (3) the *right level* of explicitness and of embeddedness of urban interfaces to support a sustainable integration into the current social, cultural, and architectural structures. In our following case study, we present the first experiences of bridging the gap between modern technological advances and the built environment. *Woodie*, an urban robot, also considers calm yet explicit interaction and connects to its surroundings on a physical, spatial, and social level.

3.2 Woodie: An Urban Robot for Investigating Physicalized Urban Displays

Woodie is a slow-moving robot that draws with conventional chalk sticks on the ground using the public space as a large horizontal canvas (see Figure 6) [27]. Like the case study *Traces-Of-Use*, we were interested in using existing physical structures (e.g., streets) as a carrier for urban interfaces without necessarily applying permanent changes. While *Traces-Of-Use* explored the modification of raw building materials as input modalities, this case study in the first place concerned alternative forms of urban displays enabled through robotic systems. By following a research-through-design approach and deploying *Woodie* as an *urban probe*, we further analyzed resulting social interactions among people and the robot.

Before putting this concept into practice, we developed a taxonomy [28] to map out the current design space of pervasive urban displays. Based on an analysis of existing pervasive display systems deployed in academic research and industry projects, we classified those approaches along two dimensions:

a) the **increasing levels of physical integration** of content into the surrounding environment (attached, blended, physicalized), and

b) **increasing levels of mobility** of the display technology (fixed, portable, self-moving). Our analysis revealed that most pervasive displays are fixed and permanently installed in public spaces, and those displays produced content in the form of an *attached media layer*. However, as earlier outlined in this article, there are recent endeavors towards more physically integrated forms of pervasive displays, and such that they are capable of changing their position autonomously. These approaches provide several advantages relevant to the pressing needs towards more adaptable, inclusive, and sustainable forms of civic information systems. For example, highly mobile pervasive displays can quickly respond to contextual changes and can be deployed in an ad-hoc manner without any long-lasting construction work required. Furthermore, display technologies producing content in a physicalized form (e.g., through manipulating the existing urban environment) enable tangible manipulation of the content without requiring access to, for example, a hand-held mobile device, or

the need to adapt to changing interaction paradigms and prevent lighting pollution rapidly. In the case study *Woodie*, we aimed to combine those two characteristics, thus creating a pervasive display system that is highly mobile and produces content in a physicalized form. Manifesting this concept through a real-world prototype, we aimed to provide initial insights about novel records of social interactions that might arise from integrating urban robots into daily urban life and revealed its potential implications. During the design process of Woodie, we were concerned with the content creation itself and considering how an urban robot needs to be designed in terms of its physical appearance, communicative features, and movement patterns. Influenced by the aesthetics of ambient media façades, we integrated a low-resolution lighting display in the outer shell for the robot to communicate its internal state and intent. Early testing further informed our decision for the robot to move slowly, not to become an obstacle for passers-by.

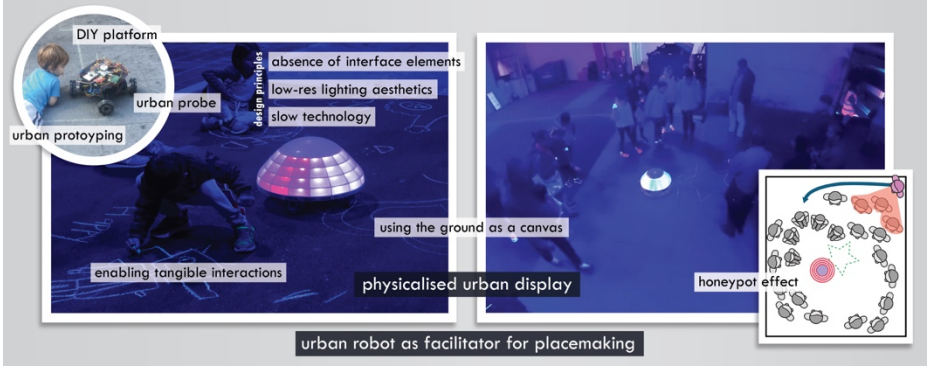

Fig. 6. Exploring emerging forms of pervasive displays enabled through urban robots: Woodie was deployed as an urban probe at a large-scale public festival.

We deployed Woodie as an urban probe for three weeks in a quiet laneway situated within a primary business and residential district. We collected data through interviews, observation notes, and video logs. In terms of the *physicalized* content, we observed similar experiential qualities previously outlined in the case study *Traces-of-Use*: for example, interviewees stated that they appreciated the chalk drawings' tangible qualities, and often we could also observe people touching the chalk powder produced by Woodie. As we provided chalk sticks to visitors to add their drawings, the contrasting characteristic styles of the human-made vs. the machine-made pictures emerged as an additional layer of meaning to the content. While in *Traces-of-Use,* participants articulated more interest towards the *imperfect* shapes; in this case, people did not favor one or the other. It felt rather inviting for visitors to explore the differences and how the characteristic styles complement one another, with people contemplating "[…] what was drawn by humans and what was drawn by [the] robot". In terms of the robot's physical presence, our interviews and observations pointed out that Woodie successfully attracted passers-by and acted as a facilitator for creative placemaking activities. Given the design's openness, not integrating any forms of explicit interaction and feedback mechanisms into its interface, we noticed a variety

of approaches regarding how people appropriated the robot. We could often observe people standing around Woodie similarly as they would to a street performer, and Woodie would then trigger a *honeypot effect,* like that observed in earlier works around (interactive) pervasive display [64]. However, as Woodie would continually add new drawings at various locations, the *honeypot effect* would disperse and shift over time, as the new drawings would create additional display spaces around which people would then gather. While some people would only observe the robot, worried about "[…] disturbing the drawing process", others would come closer or burst into short performances. We could also often observe children touching the robot or chasing it like an animal. At some stages, this behavior would also transition into the robot's abuse. I.e., children would kick the robot or even jump on it as if it were a skateboard. These observations also lead to further research questions: (1) How can we design for unintended behavior with urban robots (e.g., robot punishment [7]), and more generally, how will humans and non-human agents cohabitate in our future cities? (2) How can urban robotic experimentations, such as Woodie, be implemented on a larger scale, i.e., how can local governments and communities be supported to adapt to those emerging media architectural interfaces and ensure long-lasting innovation and social change? And finally, (3) how do we deal with the question of ownership when it comes to mobile and autonomous entities? Should urban robots be considered *social goods*?

3.3 Punishable AI: Designing Meaningful Interaction with Robotic Entities

More self-learning systems currently enter urban spaces, such as autonomous vehicles or urban robots (see Figure 1). As depicted in the introduction, the current situation of a global pandemic can further accelerate this process. For example, *zoomorphzoomorphic robots* are currently used as social distancing patrols in Singapore. As a consequence, we believe that designers and architects need to rethink interaction patterns with urban technologies. These entities often are constitute self-learning systems, and thus the design has to be optimized for AI processes instead of deterministic algorithms. The urban context poses additional challenges to this already complex domain. Urban spaces have always been and always will be an environment where people of different cultures, age groups, or social classes come together. Thus, interaction paradigms need to be understandable and meaningful for a diverse and heterogeneous group that is directly integrated into the urban social context. In the project Punishable AI [52], we created a speculative experience prototype to directly confront users with new interaction techniques for robotic training and human feedback-loops in conjunction with self-learning robots. This prototyping scenario provided information about the technology and was incredibly insightful in users' confrontations with future technologies and interaction design. Based on the widely observable phenomenon of robot/technology abuse (as observed in the Woodie field study), we investigated the users' acceptance of punishment as an AI teaching strategy. This topic has been the subject of our investigation and focused on HRI in the context of widely used anthropomorphic robot designs and interactions [15]. In addition to previously investigated interactions such as *scolding* and the use of *unpleasant stimuli*, we added a third strategy that focused on creating a high

commitment for the users based on the effect's persistence.After reviewing related work, we postulated that many of such interactions do not convey meaning to the users since their action is often stylized (cf. Milgram's Experiment with robots [2]). Thus, the effects are questionable. On the other hand, extreme forms of punishment, such as the *killing of a robot* [3] by destruction, clearly convey the interaction's effect – due to their deterministic nature. As shown in the *Traces-of-Use* study, users could grasp the causes related to a "destructive" pattern. This can help to inform the interaction implicitly. Following this observation, we were interested in creating a destructive but incremental interaction (mutilation) to communicate their interaction with the intelligent system to the user while providing certain repeatability.

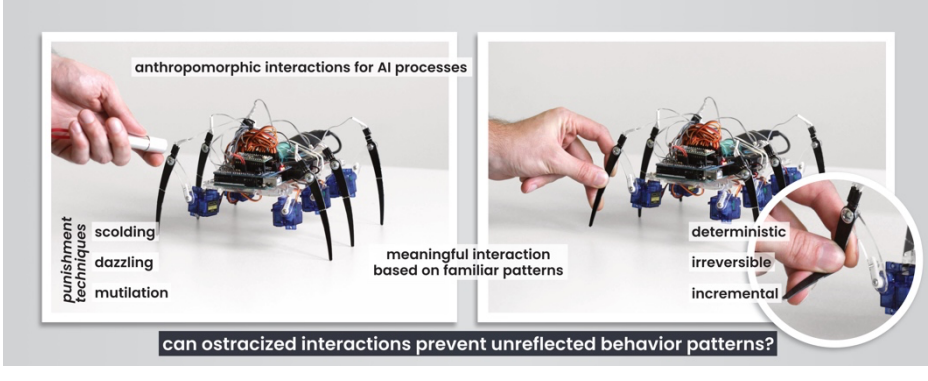

Fig. 7. Punishable AI is a provocative design exploration that questions the increasing anthropomorphizing in interaction design with intelligent systems. During the study, users were placed in a learning scenario to train a robot by punishment. The project's goal was to confront users with plans to gain insights into design challenges in human-robot interaction (HRI).

In our study setup, 20 participants experienced this teaching approach, consecutively executing scolding, unpleasant stimuli, and mutilation. It revealed that even with its highly technological appearance, the robot and the *abusive interaction* affected the users. Thus, users were aware of the effect their interaction caused, finally leading to the robot's destruction. While this creates a meaningful and understandable interaction paradigm (which all participants unanimously rejected to use under standard conditions), the question remains whether, and if so, how such human-robot-interactions could be integrated into an urban environment. We want to emphasize that this experiment was meant to provide insights about the acceptance of punishment based on a speculative scenario and not to advocate for this interaction paradigm in general. Still, the following deduced questions should be discussed within media architecture: (1) Can socially ostracized interactions with AI interfaces prevent excessive and unreflected behavior patterns? (2) Or should future urban robots and their interaction mechanisms explore new paradigms besides anthropomorphic design strategies?

4 Discussion

4.1 Five observations about where the field is moving towards

Reflecting on a changed global situation, we recognize a worldwide shift in perception towards technology. While in the past urban planners and researchers have advocated for a careful and deliberate integration of technologies into public spaces [62] the changed global situation acts as an accelerator of emerging technologies such as robotics and autonomous vehicles (see Figure 1). Simultaneously, in many countries, public spaces are just as active as ever, if not more, with various (and often conflicting) groups taking to the streets to protest and demonstrate, despite the pandemic context. We acknowledge the new role this domain is heading towards, considering the *readiness* of new technologies and the previous work in media architecture. Below, we discuss five observations based on our review of related work and our experiences developing initial prototypes of next-generation urban interfaces as early protagonists of this emerging design space. We highlight resources, such as principles and methodologies, for designing next-generation urban interfaces. With this design-led perspective in mind, we would like to emphasize that in presenting our observations, we aim to discuss the topic and raise central questions that are worth investigating further. However, we do not seek to answer any of our assumptions at this point to reflect on a media architecture approach for designing the next generation of urban interfaces and which framework it may require. We consider our initial prototype studies, which we have exemplified above, as initial probes and starting points to raise awareness of the complexity and multi-layered challenges that Media Architecture's domain is moving towards. Keeping an open consciousness on these circumstances in mind we will discuss in the following how our preliminary experiments led us to a new set of research questions we consider as a contribution worth sharing with the community.

Observation 1: Interdisciplinary collaboration and skills. Prototyping and implementing next-generation urban interfaces demand even more technical and engineering-related skill sets than those required in the past two decades of media architecture installations. Hence, we consider HCI a pivotal discipline to design the dialogue between citizens and new urban infrastructure. This is because HCI already articulates close partnerships between creative fields, such as design, architecture, and media studies, and technically-oriented ones like engineering, computer science, and their recent subfields (such as robotics, AI, biodesign). Therefore, such an arrangement is required and mandatory: only a cross-disciplinary effort can ensure the necessary balanced approach for these novel systems currently deployed in cities to become valuable extensions in an aesthetic, enjoyable, usable, and useful way.

The community of media architecture can provide a cross-disciplinary perspective and gather the responsible disciplines under one roof to foster successful collaborations. We argue that this partnership between creative and engineering-driven disciplines should not only be established on a project level. Instead, interdisciplinary cross-disciplinary education in this domain is critical to better prepare teams for potential pitfalls and misunderstandings and minimize the likelihood of failed media architectural concepts. This is especially crucial in light of the new urban technology infrastructure we have previously discussed. Once large-scale deployments of AI-enabled robotic systems have happened, many instances and artifacts of deployments might be irreversible and permanent. Therefore, pre-testing and prototyping novel interfaces and technologies with all involved disciplines in the urban domain will become crucial for determining their success and acceptance. For example, in our *Punishable AI* case study, we were confronted with the boundaries of an HCI driven implementation perspective. Ethical considerations, as well as technological constraints and possibilities, provided the basis for this project. Along the course of development, we've teamed up with artists, engineers, e-learning researchers, and HCI scientists to frame development, integration, and social-ethical design considerations for the study setting. This is a study setup that cannot be solved by an individual discipline. We conducted the study in a closed lab setting that was intentionally designed for critical thought-provoking reflection of the invited participants rather than confirming concrete, task-oriented use-cases. Yet, the tackled IxD challenges might be transferable to the urban context as we face increasing interactions with humans and non-human agents in the urban domain. Hence, we argue that future practitioners' skillsets in this context need to be extended even further than just teaming up design with engineering-related disciplines. The increased technological challenges demand a large amount of electrical/robotics engineering. Additionally, to enable meaningful interaction, the skillset needs to be extended by considering people's psychological, philosophical, and ethical norms, habits, and standards while in dialogue with a machine.

Observation 2: Environmental awareness. As described in our *Traces-of-use* case, we react to environmental issues and challenges such as lighting pollution and energy consumption, promoting eco-friendly design concepts and strategies. We have exemplified an approach to reuse and repurpose materials and non-light emitting interfaces that might fit seamlessly into the urban environment and provide better human comfort than ubiquitous touch screens. This challenge will be a persisting issue and change the designers' mindset of the next generation of media architecture. Since cities are hotspots for the effects of climate change as they are explicitly vulnerable to flooding, heat absorption, and issues through population density, we believe that a sustainable design approach is unavoidable for the consistent well-being of humans and other living beings. Working with renewable and eco-friendly materials in media architecture addresses these issues. As presented in the *Woodie* case study, the content may also be degradable, thus fostering a more careful utilization of resources.

Observation 3: Local specificity and global relevance. As we have concluded from our previous research [18] and the cases presented here, urban interfaces must consider an urban space's local context. Their design and deployment need to respond to the physical characteristics of the space, the needs and behaviors of urban dwellers, and possibly non-human stakeholders [58]. This poses a significant challenge when designing interfaces, as urban areas can significantly vary across countries. Even within a city, urban dwellers' needs and behaviors can dramatically change whether, for example, we are designing for a central business district or suburbia. Demographics also vary from suburb to suburb and region to region. Ignoring these differences affects the success of urban interfaces negatively, such as urban screens [57]. As we start dealing with more pervasive and more mobile urban interfaces that can autonomously move from site to site, these local specifics become more challenging to address. Indeed, it might be necessary to find a new paradigm for next-generation urban interfaces to respond to their local environment. Experimental media applications can inspire this development. For example, an outdoor media company trialed adapting the programming for the content of a digital advertising screen on the side of a bus to show location-based content [55]. The interfaces from our own cases were designed for a specific urban environment (i.e., *Woodie*) or to investigate a particular interaction aspect (i.e., *Punishable AI* and *Traces of Use*). Through iterative prototyping, we were able to refine how the interventions responded to the local context. However, as our cases remained prototypes only (at this stage), we did not need to tackle scalability and deployability questions across different locations. A useful approach for responding to this challenge is to 'think in prototypes' [68] and follow an iterative process.

Observation 4: Social, aesthetic, and spatial dimensions. Related to the previous point, and as argued and demonstrated in many years of research on media architecture, the integration of digital media and technologies into urban spaces needs careful consideration [52] and should avoid a *big bang approach*. For an intervention to be successful, those considerations must integrate social, aesthetic, and spatial dimensions [13]. In the case of *Woodie*, we drew on media architecture principles to design the urban robot as an artifact for a specific city context and prompting the augmentation and social activation of public space. Our field study revealed various patterns in how passers-by engaged with the urban robot individually, in small groups, and in large crowds [27]. For the communication interface, we employed low-resolution lighting principles to achieve an aesthetic effect that resembles the way media facades activate urban spaces at night. *Woodie* addressed the space's spatial character in which it was deployed through its circular shape, allowing people to approach it from all directions. At the same time, it activated the space through its ability to draw chalk graphics onto the road, thus, over time changing the aesthetic, spatial perception, and use of the area by passers-by.

Observation 5: Socio-cultural interactions and temporal dimension. Objects in public spaces do not exist independently but evolve due to a co-evolution of artifacts and the interactions people have with those artifacts [57]. Therefore, the design and deployment of urban interfaces need to respond to the temporal dimension [57] of this co-evolution and to how this interdependency between artifacts and social interactions changes over time. Even though the form of 'media' in media architecture interventions is shifting to encompass emerging technologies, the resulting artifacts have an equal if the not more pronounced impact on the cultural setting in which they are embedded. As such, the design principles for creating urban media environments provide a useful framework for addressing the specific challenges of a public space that are linked to its cultural dimension [57]. For example, in the case of *Trace-of-Use*, we applied familiar usage patterns that are based on common, repeated behaviors. Hence, they are implicitly understood by the individual due to the shared, socio-cultural knowledge. While we tested the strategy in a lab environment only, the need for a common design language for public urban interfaces is evident. The *Punishable AI* case study questioned the interaction between humans and AI-enabled robotic systems. As we have presented earlier in the article, these systems are currently being deployed in global cities. However, these systems have been created and designed mostly from an engineering-driven perspective. Case study deployments over longer periods still lack a thorough reflection and evaluation of the mutually sustainable dialogue between citizens, robots, and the environment. Therefore, in our *Woodie* case, we deployed a self-moving system capable of influencing the environment and passers-by's behavior and movement via printed images and notes. Initial observation setups were tailored to investigate people's emerging interactions with new technologies in their familiar surroundings. *Punishable AI* instead questioned the ethical role of punishment mechanisms for robotic systems and people's reactions to those. When we envision the large-scale urban deployment of these systems in the near future, interactions between citizens and robots have to be provided beyond the smartphone-based interactions copied from web-based systems as they do not apply to spontaneous interactions with all age and culture groups of humanity.

4.2 Key takeaways and emerging questions

Considering the depth and level of detail of the provided challenges and case studies, we want to emphasize again that we explicitly aim to discuss the paradigm shift of media architecture on a holistic level. Our novel challenges in this domain are briefly reflected from an HCI and design-oriented perspective. Hence, discussing related work on the obstacles misses out on the engineering-oriented perspective, which needs to be considered for the successful implementation and long-term deployment of these projects. In the context of a newly initiated long-term research project, we will team up with electrical engineers and scientists working in robotic systems to further substantiate our challenges from a merely technical perspective. The cases illustrated possible approaches for early urban interventions using novel technologies, sensors, and prototyping approaches. Here, we focused on the experience prototyping

aspects that make new *ideas tangible* at an early development stage and allow iterative pre-testing. More specifically, those early prototypes can be tested in secure, controlled environments, isolating many of the challenges so that designers can focus on finding out about users' preferences and needs. We consider those individual case studies with a high-level perspective to enable discussion of interaction design and architectural strategies without getting tied up in extensive study data, which might be misleading for a general discussion of the topic presented in this article. Hence, we consider the cases as initial probes into the new design space of media architecture. Each case and each challenge need to be investigated through further case studies, prototype explorations, and summative evaluations in the coming years. The five observations described in this section provide a roadmap for structuring future research on the next-generation of urban interfaces and the development of the field of media architecture more broadly. For example, we need more research to identify frameworks for people from various disciplines working together and ensuring that the end product is not dominated by one specific disciplinary perspective. This will need to include the development of new prototyping toolkits that allow people without the technical engineering background to design, prototype, and test next-generation urban interfaces. Potential research questions for future research are outlined in Table 1.

Table 1: Considerations and research questions for future research on next-generation urban interfaces and the field of media architecture based on related work and our own case studies

Observation	Case studies	Research question(s)
#1 Interdisciplinary collaboration and skills	Punishable AI, Woodie	How can we move on from urban robotic experimentation to long-lasting innovation? How can we support local governments and communities to adapt to those emerging technologies?
#2 Environmental awareness	Traces-of-Use, Woodie	How can we redesign and augment existing places sustainably to comply with new technological trends and societal requirements? How can next-generation urban interfaces themselves use more sustainable materials?
#3 Local specificity and global relevance	Traces-of-Use, Woodie, Punishable AI	How can we design for local relevance while still ensuring scalability and deployability across different locations?
#4 Social, aesthetic and spatial dimensions	Traces-of-Use, Woodie	How can we intertwine the old and the new, bridging the gap of generations of media architecture, and society and technology through media architecture?
#5 Socio-cultural interactions and temporal dimension	Punishable AI, Woodie	How can socially ostracized interactions with AI interfaces prevent excessive and unreflected behavior patterns?

We consider the set of questions depicted in Table 1 as initial starting points investigating different areas that the domain of media architecture is heading towards. Clearly, each one of them imposes a set of multiple questions that go into more detail and need to be substantiated further. This will be the subject of our current and future research work.

5 Conclusion and Future Work

In this article, we reflected on the development of media architecture over the past two decades, linking its development with work done in related fields, such as smart cities and HCI. We argue that the field is shifting from a focus on light-based spatial media installations towards an ecology of sustainable/reusable interfaces of various scales and agency levels. While this article provides a high-level reflection, proposing a paradigm shift towards new forms of urban interfaces, we also continue investigating the steps needed to implement this paradigm shift in practice. To that end, we currently work with a team of robotics engineers and urban planners on an autonomous mobility research project: Using a fully functional automated vehicle as a platform, the project enables us to translate media architecture principles (for example, to implement the way the vehicle communicates with pedestrians) as well as interaction design principles (for example, to program the way the automated vehicle responds to gestures performed by nearby people either implicitly or explicitly). Drawing on research from the field of HCI, we are investigating new approaches to prototyping these complex platforms in a form that allows us to test those prototypes with stakeholders in a low-risk environment. By substantiating our research work further, we aim at creating meaningful interaction design for media architecture to enable citizens to deal better with the contemporary global challenges. As outlined in the article, the field of media architecture offers a complimentary foundation by emphasizing social, spatial, and aesthetic considerations. We demonstrated how "media architecture thinking" nested with HCI methods and methodologies can reveal new applications of next-generation technologies through our case studies. The advantage of a media architecture approach here is that it starts from a realistic account of what is possible (in terms of the technical possibilities) and how things currently work (in terms of social considerations) while creating speculative but tangible narratives of what could be (through design prototypes). By identifying five dimensions for next-generation urban interfaces, we contribute a foundation for future work, such as urban robotic systems, and the field of media architecture more broadly.

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