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General Article

What does Augmented Reality Mean as a Medium of Expression for Computational Artists?

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Abstract

As augmented reality (AR) quickly evolves with new technological practice, there is a growing need to question and re-evaluate its potential as a medium for creative expression. The authors discuss AR within computational art, framed within AR as a medium, AR aesthetics and applications. The Augmented Reality Immersive Instruments (ARImI), a two-day forum on AR, highlights both possibilities and fundamental concerns for continuing artworks in this field including visual bias, sensory modalities, interactivity, and performativity. The authors offer a new AR definition as *real-time computationally mediated perception*.

Augmented Reality in a broader context

Augmented Reality (AR) has seen recent resurgence with new tools, user interfaces and related algorithms. In some respects these technology are stabilising (e.g. new mobile AR frameworks), however within the arts, AR technology is arguably still in early development [1] and are just beginning to see wider use by creative practitioners. Despite this early stage of development, AR technology are becoming available to the masses in ubiquitous forms (mainly through gaming and mobile technology), and these new platforms are providing new

ways of creatively altering our perception of the environment in more detailed, nuanced, multisensory, timely and perceptually believable ways than were previously possible. This is happening above a rising base-level of pervasive technology as it and its data merge both ‘physical and mental constructs’ [2].

We see computational arts as a practice centering on the creation of interactive artworks that are fundamentally algorithmic (probably digital, but possibly, for example, biological, mechanical, analogue). In the context of expressive media for computation arts, we define AR as *real-time computationally mediated perception*. *Mediated* because there is the potential for the ‘Augmented’ in AR to be a transformation of the environment as opposed to an overlay, as we typically see in functional AR systems (e.g. mapping apps). We understand the term *mediation* as subsuming *augmentation*. *Realtime* because AR responds to present events, and builds mediations with a temporal connection to these events. *Computational* in that an algorithmic process or automaton senses the environment and creates *mediations*. We choose *perception* in preference to *reality* as new AR technology invites new forms of perception and sensory situated experience, made possible through *mediation* that no longer nuances one reality (real or virtual) over another, instead approaching them as one environment, as one relational system.

To explore this, we map-out ways in which new AR technology might be applied as a medium for creative expression. We do this through (1) building on discussions of AR as a medium and related aesthetics, (2) locating a genealogy of AR, (3) AR applications, focusing on sensory *mediation* and interactivity and through (4) forum discussions and a multi-disciplinary overview on AR [3].

This discussion contributes to current discourse concerning AR technology as a medium for computational artists, and explore AR’s virtual and physical relations and boundaries.

What is Augmented Reality? From apparatus to social experience

Early AR explorations [4--6] were predominantly formed around Head-Mounted Display systems (HMDs), primarily for aerospace applications [7]. By 1997, Azuma [8] defined AR as a combination of three key characteristics: 1) combining real and virtual, 2) realtime interactivity, 3) 3D registration. This original conception of AR tended towards the visual,

but acknowledged a broader range of technology and forms of ‘augmentation’ (e.g. haptic, auditory, etc.) [9-10]. It is key to mention that Azuma’s position defining AR is based on the user’s perception as opposed to a *mediation* of the environment itself: “*Augmented Reality enhances a user's perception of and interaction with the real world*” [11].

With the advancement of HMDs and ubiquitous mobile video technology, visual ‘augmentation’ has been the dominant area for development within the field [12] as it began to cross over different practices in the arts, science, and education, and began to reach popular culture delivered in predominantly visual forms (e.g. gaming, advertising, navigation). In doing so, AR began to shift from apparatus to social experience [13]. This focus on visual ‘augmentation’ obscures our understanding of what AR is and can do in relation to other sensory ‘augmentations’, and as a medium for broader creative expression.

The medium and aesthetics of AR in Computational Art

Our own position on art and expression draws from the philosopher and psychologist John Dewey’s discussion in *Art as Experience* [14]:

“The poetic as distinct from the prosaic, esthetic art as distinct from scientific, expression as distinct from statement, does something different from leading to an experience. It constitutes one.”

“[...] objects of art are expressive [...] they are many languages.” For each art has its own medium and that medium is especially fitted for one kind of communication.”

Our own position on art and expression, is locating it as a set of relations between experience, materials and environment - all physical, digital, symbolic - as languages from which new knowledge and new modes of communication are made possible.

AR art invites multimodal design practices (e.g. 3D graphical, interaction, user experience, interface, spatial, multimedia) and inevitably draws from other media forms [15] whilst inviting collaborative practice. Consequently to think about AR as a medium it is to think of a multimodal set of relations between technology and environments (both real and virtual and inclusive of participants corporeity) within a ‘cultural matrix’ [16].

In doing so we are not limiting AR to one aesthetic within a medium-specificity, but instead think of its medium as a set of relations that initially builds on Azuma's definition. The parameters are broad but this is central to enable AR to develop as a language for cultural expression [17].

Discussions on AR aesthetics [18], although still highly reflecting the visual bias and heavily grounded in the screen-based media genealogies (e.g. lantern slide projection, cinema), approach AR as being: user-centric [19], mediated [20], a blending of virtual and physical reality [21] and interactive [22]. Geoffrey Rhodes [23] also begins to discuss AR as an inhabited environment from which the digital and the physical 'co-produce and co-construct one another', from which expression can be found in its 'enmeshment'. Consequently, we propose to trace a genealogy of the use of systems as aesthetics towards sensory social experiences.

Early aesthetic theorisation of systems as artistic media becomes relevant to current thinking about AR. In the reconception and theorisation of art objects towards system aesthetics, Jack Burnham [24] states how System Esthetics is an approach to "*a socio-technical conditions rooted in the present*" as he attempts to move away from art's object-oriented culture to a process-oriented culture. Nicolas Bourriaud's Relational Aesthetics [25] introduces art objects as part of "*the realm of human interactions and its social context*", highlighting how art objects reside in relation to various environments (e.g. cultural, natural, synthetic) and forms of interactivity. In addition, Burnham [26] sees computation as a way to dissolve the boundary between art and the environment [27], in a sense envisioning some of AR's characteristics, leading us to interactive aesthetics from which both physical matter and objects operates in relation to the participant's corporeity activated by actions and processes [28].

AR in the Computational Arts

To contextualise this discussion, we introduce some early and contemporary artworks that we consider to use AR as their primary medium. These are not intended to provide a comprehensive review of artworks in this field, instead, they offer examples of varying sensory modalities, modes of artistic expression and participants' experience, reflecting Azuma's original definition and its contemporary adjustment.

Jeffrey Shaw's *Viewpoint* (1975) [29] is an early non-digital experiment, where a viewer and slide projections constructed a perceptually contiguous layer over the seen environment. Shaw continued to pioneer AR in *Virtual Sculpture* (1981) [30], where a moveable viewer layered 3D wireframe objects onto the surrounding environment. These works merged composed content with real environment, and were passive installations.

Since this pioneering early work, advances in digital technology have enabled new forms of AR artwork. Mobile AR has become more popular, where viewers use their screen as a window into the real world, with composed augmentations-based on camera and sensor input. For example, Thiel's *Gardens of the Anthropocene* (2016) [31] adds a futuristic landscape in the form of sculpture to Seattle Art Museum Olympic Sculpture Park using a mobile app. Similarly, Veenhof and Skwarek (2010) [32] curated a 'guerilla style' exhibition of 3D artifacts displayed virtually, inviting AR artists to display their work in the space of Museum of Modern Art (NYC).

Mobile AR has given potential for involving new participants and to locate AR as public art, whilst bridging public and personal space. AR here and in Shaw's artworks follow a layering paradigm where the virtual objects are predominantly additions to the real world. Levin et. al's *Augmented Hand Series* (2014) [33] steps beyond the layering paradigm, creating transformations of the 'real' world; participants see a reimagined view of their hand when placed in a viewer, for example by adding and removing digits or warping the the hand's shape. The work is particularly interesting as it-exploring how AR might change participants perception of their bodies and senses.

Mobile technology has opened-up possibilities for sound-based AR experiences, with apps such as *RJDJ*, *Inception* and *H__R* [34]. This app series performs live re-processing of sound environments. The artwork takes the form of sound and sensor processing algorithms, to be experienced at any time or place. Sound technology crosses over into new haptic possibilities. In *ListenTree* (2014) [35], a tree is excited with sound transducers; the participant can both feel the vibrations and listen to the sound using bone conduction technology.

New developments in AR technology bring together 3D graphics and spatial audio towards immersive experience. The potential of Microsoft's HoloLens (2016, a holographic HMDs) in

an installation art environment is explored in Studio Drift's *Concrete Storm* (2017) [36]. Participants experience virtual extensions to the bases of real concrete posts that defy natural physical limitations. This was the first piece to use this new technology for a multi-participant installation through a replicated experience across multiple headsets.

We restate that these are examples of the way in which AR has been used as a medium for artistic expression. These examples are tied in with the progression of technology, and there are AR technology that have yet to see significant use by artists (e.g. Microsoft HoloLens, Ultrahaptics, Wavefield Synthesis [37]). In addition, in thinking about AR aesthetics and drawing these works together, we observe the following points: (1) AR is being used to render data visualisations upon the environment, but the possibility of merging environments, seems closer especially with Audio AR and its transcendent quality. (2) Technology lending new possibilities with participants, environments, performativity and levels of interactivity between them. In particular when considering the role of the participant's corporeity. (3) New potential for increasing immersion, believability, and creation of detailed and nuanced interactions. New technology and media open up novel modes of cognition [38], perception [39] and creative expression.

To think further about AR as a medium of expression for computational artists we organised Augmented Reality Immersive Instrument (ARImI), a two-day forum, looking at broader multi-disciplinary applications in AR, to inform new thinking around creative practice.

The Forum for Augmented Reality Immersive Instruments (ARImI)

The Forum for ARImI brought together multi-disciplinary participants in discussion around constructing and deconstructing AR experiences, exploring new forms of creation and perception. Two days of discussions led to a collection of open questions concerning AR and the arts. Day one, *Mapping AR*, saw presentations from participants with artistic, scientific, cultural and/or third sector backgrounds, with themes of culture, sensing, instruments and the arts. On day two, *Hacking AR*, participants explored AR practically through an 'unplugged' workshop where groups built and discussed hypothetical AR technology, and a 'plugged' workshop where groups experimented with off-the-shelf AR technology, using visual (mobile apps, HoloLens, cardboard VR), audio (mobile apps, bone conducting headphones) and haptic (tactile transducers and ultrasonic tools) materials.

Questioning AR as a Creative Medium

In wanting to clarify the nature and potential of AR as a creative medium, the Forum for ARImI raised a number of questions. Much discussion related to authorship and data production in AR installations, interdisciplinary collaboration, ethics, political and economical constraints. These all fully warrant critical attention. However, for the purpose of this discussion we focus on questions that build from Azuma's definition, with its perspective on perception and multi-modality:

- (1) In thinking about the **combination of real and virtual**, we are considering them as one environment.

How will mediations be temporally connected between participants and environment? Will mediations be calculated from past events as well as in-the-moment events?

- (2) **Realtime interactivity.** Here we focus on asking how machines enable expression between the participant(s) and an AR artwork?

How is the role of the participant changing in AR artworks? How do sensory mediation and new forms of representation, shared authorships as the artworks enable creative expressions, enable data collection? With potential for new kinds of immersive experiences, is there a need to revisit ethical considerations in interactive art?

How will participants express themselves in AR environments? How does the choice of technological engagement with the participant permit or limit the potential for expression? (E.g. through wearable and mobile technology or altered environments).

- (3) **3D registration.** We interpret this in a broader multisensory context, as the way in which mediations are embedded within the environment.

What is the nature of 'augmentation'? Does 'augmentation' mean to layer, or could it also mean to mediate (transform, enrich, enhance)?

- (4) **Mediated perception:**

Which senses will be mediated? How will multisensory works manage the interplay between sensory modalities?

How might AR alter cognition? If we follow Clark and Chalmers [40] view cognition extends into the environment, AR can then transform cognition by intervening between body and world.

Conor McGarrigle [41] states “*Augmented Reality is a problematic term in itself but [...] we’re stuck with it*”. It can be useful to view AR as an area of a spectrum between experiencing the world ‘as is’, and total immersion in a computationally generated experience, as proposed by Paul Milgram and Fumio Kishino [42]. This original proposal took into account sensory modality; for contemporary AR in creative practice, this spectrum envelopes additional dimensions: participant(s), environment, technology, interactivity, and performativity.

Returning to original question ‘what does AR mean as a medium of expression for computational artists?’ We have investigated the development of AR from an overlay technology towards a medium with nuanced, immersive and transformational potential. We have also shown the expansion of the participant’s environments with AR becoming a shared social experience bridging public and personal spaces. New AR technology is seeing nascent use by artists, with far more potential for creative exploration.

We have suggested that centering on a contemporary understanding of AR is vital to creative practice. Within this context, we proposed to conceptualise AR as *realtime computationally mediated perception*. The questions identified at the ARImI forum can be used to frame further AR thinking and practice. New AR technology is seeing nascent use by artists, with far more potential for creative exploration.

Moving forward, we re-iterate Rhodes [43] points around AR as an inhabited environment where digital and physical ‘co-produce and co-construct one another’, and suggest that an ecosystems approach-based on Agostino Di Scipio’s work [44] could be beneficial to creative practice. His work explores the inseparability of humans, autonomous systems and environment, and the emergent properties of this relationship within the concept of an ecosystem. Di Scipio’s work [45] focuses on sonic ecosystems, we could also see AR as inseparable from a multisensory ecosystem, inhabited by modes of sensing, modes of

perceptual mediation, computational relationships between sensing and mediation, human participants, and their environment. In this way, we consider AR within creative practice as a medium for creating new nuanced and fine-grained emergent aesthetic experiences.

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