Exhibiting Mutator VR
Procedural Art Evolves to Virtual Reality

WILLIAM LATHAM, STEPHEN TODD, PETER TODD
AND LANCE PUTNAM

ABSTRACT
Organic Art (William Latham and Stephen Todd, 1987) was reincarnated by the same authors with programmer and artist Peter Todd as Mutator2 (2013); Mutator2 was transitioned into VR as Mutator VR (2016) with programmer and artist Lance Putnam. The authors describe the graphics and audio systems of these works, particularly the procedural generation and visual effects and the creative exploitation of these effects within an art installation. The authors mix "real" and "unreal" features and effects, inspired by surrealist art, to create highly immersive psychedelic organic experiences for the viewer-participant. Interface simplicity and discoverability is critical for VR exhibitions, as is the balance between an experience constrained by an artist’s choices and a freer (but riskier) one with greater public choice. Public gallery installation of Mutator VR creates special challenges.

INTRODUCTION AND BACKGROUND
This article discusses the authors’ Mutator exhibitions from 2013 to 2018 [1]. The exhibitions evolved from earlier evolutionary artwork at the IBM United Kingdom Scientific Centre (UKSC) in the late 1980s and early 1990s by authors S. Todd and Latham [2], which we named Organic Art. The artistic style of Mutator2 from 2013 to 2016 is based on the older Organic Art work, but we exploited advances in technology to permit real-time interactive exhibitions using a range of platforms from touch screen to Kinect. There then followed a transposition of the technology to virtual reality (VR), and since 2016 the work has become known as Mutator VR. In this article, we describe our creative work in exploiting these new capabilities and the challenges we faced.

Related Works and Influences
In our work, we use an interactive, generative approach to create abstract worlds, in contrast to the figurative content of many contemporary VR artists, as in Paul McCarthy’s Coach Stage Stage Coach (2017) and Christian Lemmerz’s hanging golden Christ figure in La Apparizione (2017) [3]. Early abstract computer art by Herbert Franke and other algorithmic artists from the 1960s and 1970s [4], and later evolutionary systems such as Richard Dawkins’s Biomorphs [5] and Karl Sims’s Galapagos [6], influenced our procedural approach. Prampolini’s “futurist scenography” [7], reflected in earlier VR works such as Home of the Brain (1992) by Monika Fleischmann and Wolfgang Strauss and Osmose (1995) by Char Davies [8], motivated us to create a viewer-driven performative experience with dynamic abstract imagery. Our work also shows strong surrealist influence [9] in its creative use of chance, with rich texturing, dramatic lighting and strong shadowing. The psychedelic imagery of 1990s rave culture (e.g. in Latham’s visuals for The Shamen) [10] is another influence on our work.

Summary of Earlier History
Authors S. Todd and Latham met at IBM UKSC in 1987 while working on a project exploring the potential for artistic exploitation of scientific visualization software [11]. In that project, we augmented the FormGrow grammar [12] of mathematical rules, inspired by nature, with mutation for subjective exploration of form space [13] and keyframe animation for video generation [14]. We have used these tools and approaches in our work on Mutator2 and Mutator VR, as described in the System section.

Our early exhibitions of Mutator2 involved large computer-generated prints and videos [15]. Rendering times of two frames per hour on mainframe computers precluded interactive exhibitions.

Outline of Article
We began the Mutator2 project in 2013 (Fig. 1). In this project, we preserve the essence of the late-1980s software we used...
at IBM but exploit modern hardware permitting real-time interaction and stereo VR. This article describes how our exhibitions evolved over five years and details the creative, UI and technical challenges we faced moving from touch screen mutation to Kinect to VR.

The article contains three major sections. The first section presents our artistic motivation in developing Mutator2 and Mutator VR: our desire to attain a balance between reality and unreality in the work and to explore the degree to which an artist’s choices constrain user options, thus directing the experience. The second section summarizes the system capabilities underlying Mutator2 and Mutator VR. The third section covers gallery experiences, especially the VR aspects. The procedural nature of the system pervades all these: The way the system behaves and is implemented are dependent on its procedural nature.

**ARTISTIC CONSIDERATIONS**

Our artistic aim is to create an immediate immersive experience for users, a surreal space operating under unreal rules, in which users quickly realize that their actions directly impact the space. The immersed user gains a sense of wonder, interacting with the surrounding dynamic 3D organic forms. Heeter’s discussions of presence describe the concepts involved [16].

The 3D forms are deliberately reminiscent of natural forms such as ancient fossils, orchids, skeletons and strange animal horns, but are ambiguous and open to users’ interpretations. Users experience occasional moments of unexpected visual beauty as their organic world unravels around them under their direct influence. Through the presentation of alien and familiar forms, the experience uses a consistent artistic framework that adapts to the user, from the most naive to the most experienced.

This section discusses four artistic concerns: finding the artistic balance between reality and unreality; finding a balance between artist-constrained interactive experiences and open public interactive experiences; catering for different users; and the gallery environment surrounding the interactive system itself. In the exhibitions during this period (2013–2018) the gallery environments have included hung artworks, large scale projections and printed translucent curtains with Mutator imagery.

**Real/Unreal**

Reality mixed with unreality provides surreal artistic experiences; forms appear simultaneously natural and unnatural. We use “real” here to mean “matching users’ familiar experiences” and “unreal” to refer to forms unfamiliar to users [17]. Achieving the right balance applies to our still images in the 1990s and is especially important in VR with users’ increased sense of immersion. If the experience is too real, the surreal intention of the work is lost; if the experience is too unreal, users will become disoriented and lose interest. A mix of real and unreal elements—for example, abstract floating objects with realistic lighting casting perfect shadows—is essential in the surrealist paintings of Dali, Magritte and Ernst. Table 1 shows the balance of elements we used in Mutator VR.

**TABLE 1.**

<table>
<thead>
<tr>
<th>Mutator VR Feature</th>
<th>Real</th>
<th>Unreal</th>
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<tbody>
<tr>
<td>FormGrow: Pseudo-Natural 3D Organic Forms</td>
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<tr>
<td>Nonrandom: geometric forms</td>
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<td>3D forms self-intersect</td>
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<td>Cutter: not realistic but feels natural</td>
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<td>No gravity: surreal floating forms</td>
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<td>Standard Perspective</td>
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<td>True eye height: avoids confusion</td>
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<td>VR room orientation: matching reality</td>
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<td>avoids nausea</td>
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<td>Room/viewer scale changes:</td>
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<td>Alice in Wonderland effect</td>
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<td>Lighting and Shadows in style of Salvador Dali</td>
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<td>Torch flashlight and headlight: increase immersion</td>
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<td>3D Textures: Objects Move through Texture</td>
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<td>Feedback: but not true raytracing</td>
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<td>Synthesized audio</td>
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<td>Recorded sounds</td>
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A balance of “real” and “unreal” features in Mutator VR creates a surreal aesthetic.

**Artist Constraints versus Public Freedom**

Artist constraints on artworks provide relatively limited but more compelling user experiences. Freer user choice offers more variety [18]—users gain a sense of exploring the unknown—but with increased risk of missing the best experiences or enduring bad ones, such as the user’s view being blocked by a giant single primitive shape or filled with boring patterns. Constraints are especially valuable when exhibitions limit exploration time by the gallery visitor.
Fig. 2. Mutator VR mapping of body positions to genes. Top: Vive controller input and arm movement mappings to gene changes that mutate the form. Bottom: image of scene and interacting user. (© William Latham. Software: Stephen Todd, Lance Putnam, Peter Todd.)

Fig. 3. Gallery environment of Mutator VR shows at the CYLAND Hybris exhibition, Venice (2017), and at the East Gallery, Norwich, U.K. (2016). (© William Latham. Software: Stephen Todd, Lance Putnam, Peter Todd.)
Our creative team of artists and software designers constrain the forms for our exhibitions with associated "genes," limiting maybe the number of branches or the twist of each branch. The procedural system allows varied levels of constraint via "per-gene limits," controlling the forms seen and how they animate. Closer limits give less variety but more artistic control.

Artistic ideas about user control also provide interaction mappings, relating movements and controller buttons to changes in the user experience.

Different Users
Central to any experience is the speed of change. Some users like stillness to savor visual richness; others like fast-moving effects. Some users are novices; others are experienced gamers used to handling and interacting with controllers. Body movement interaction provides a variety of speeds in a natural way.

Even if the user does not follow interface details, we avoid confusion by ensuring that (a) each interaction has discoverable consequences and (b) as far as possible, there is a natural (kinesthetic) correspondence between cause and effect (Fig. 2, bottom). This is critical in any user interface, more so in VR, and still more when users' VR experiences last only a few minutes.

Full Gallery Environment
Our gallery exhibitions include a large projected view, showing the VR user's view in real time; this entertains people queuing for the VR. When we showed at SHOOM 30 we projected the live view onto the floor below the user. For added impact, the VR exhibition space includes related stills and videos: 3m-wide hanging translucent curtains and decorated walls and floor (Fig. 3).

There are sometimes gaps in an exhibition with no human VR interaction; here, the system switches to a single linear path giving a sequence of parametric 3D mutations (which we refer to as an automated piste) based changes for a continuous live view, drawing viewers in.

Evaluation
Users' facial expressions during the experience and comments after ("weird" is the most common, matching the intended aesthetic) are our best indicator of whether we have succeeded. We have no formal evaluations but have sometimes collected short questionnaires from users. To date these questionnaires have received very positive feedback and yielded comments that have been used to revise our software and the user interface design.

In the future, we plan to instrument the system to collect detailed data such as time spent within each experience and how rapidly users learn how to interact with the software, for example, by moving their arms and pressing buttons.

THE SYSTEM
The system uses the GPU for all geometry and graphics, mid-range (Nvidia 770) for interactive exhibitions and high-end (Nvidia 1080, HTC Vive) for VR. The browser-based software uses JavaScript, WebGL, three.js and WebVR.

The following subsections discuss software features in two parts: form and audio grammars, and user interaction strategies.

Procedural Models
This subsection summarizes the underlying Mutator2 form and audio generation models and the graphical rendering environment.

The Mutator2 form generation model is inspired by nature, in particular by twisting animal horns we observed in London's Natural History Museum. The generation model gives almost real structures but does not mimic nature, creating tension between real natural and unreal geometric forms. Random elements bias toward reality; we favor a nonrandom, unreal look. The concepts are close to L-Systems [19] and derive from FormSynth hand-drawn evolution [20].

A horn is generated by repeated geometric transformations with names such as bend, twist and stack. Horns are nested hierarchically to produce more complex structures (Fig. 4).

Fig. 4. Horn structure.
Top: basic horn generation.
Bottom: complete horn structure showing parts; uses 92 geometry genes. The UI distinguishes red "tail" horns (gray in print publication).
Original details are described elsewhere [21]; recent extensions for VR are described in the VR Model Features section.

FormGrow structures contain parameters (genes) describing the degree of each bend, twist, etc. Changing genes (genotypes) express themselves by reshaping the form (phenotype); the underlying structure is unchanged, but the external form is dramatically different. Genes underpin all the shapes, colors, textures and audio structures produced by the procedural system. Constraining or freeing these genes provides artist control that determines the character of the user experience.

Audio is rendered by the SuperCollider synthesis server [22]. Primitive synthesizer modules such as comb filters and oscillators provide sound generation and manipulation. As with FormGrow, these combine into higher-level gene-controlled structures for audio processing, routing and spatialization. Correlating audio and graphical genes relates sonic and graphical elements. Hybrid physical modeling and subtractive synthesis combined with field recordings (birds, whales, etc.) gives an unnatural but almost organic sound, forming a gradually evolving ambience with real and unreal elements.

The forms have surface attributes [23]. A 3D noise texture [24] sampled at the surface defines color bands, which may be sharply separated or smoothly merged. Each band has genes to describe RGB, gloss, reflectivity and other conventional lighting model features. Another 3D texture seeds bump-mapping. Iridescence and fluorescent bands enhance graphical richness. The surreal style derives from "real" lighting combined with "unreal" textures.

Organic 3D forms in a black void are effective with still images [25]. A surrounding room using a rendering model similar to the 3D form provides context and richness in interactive or VR environments.

Feedback uses the previous frame for environment mapping within the current frame. This gives low-cost visual richness; for example, the Fractaleid app [26] creates a wide variety of patterns using only feedback. By varying feedback strength over the surface, it is possible to produce notable interactions between feedback and texturing (Fig. 5). Bump-mapping feedback normals distorts the effect, and iridescence richens color variation. Superficially, feedback emulates real reflection, with lower performance cost than traditional ray-tracing.

**Movement, Change and Interaction**

Movement and change are a major part of the experience, driven by

- Direct user interactions such as full body (Kinect) or controller (Vive) movements
- Mutation to a new form
- Continuous change through keyframes (for video generation) or other trajectories (for continuous animation)
Each of these changes is implemented as a two-stage process. The driver of the change modifies the genes (genotypes), which in turn express themselves as changes in the form and audio (phenotype). We discuss the process of mapping interactions to gene changes in the Interaction in VR section; we discuss mutation and animation in a previous publication [27].

Our first Mutator2 exhibitions in 2013 allowed high-level control over form mutation using a touch screen. Users combined parent forms into a child form in a large central pane. The child was continuously animated with user-controlled rates and was projected floor to ceiling for noninteracting visitors to see (Fig. 6).

We later used Kinect for direct user control of form genes. Users participated in a collaborative creative experience, with one person controlling mutation using the touch screen and another interacting by moving their body, captured by Kinect.

Body tracking of the user using Kinect encourages mixing smooth and sharp rhythmic changes. Visuals and audio follow the same pattern of change: Complexity emerges from three-way interactions among users, graphics and audio.

VIRTUAL REALITY

The technical move to VR was straightforward given suitable hardware and software. However, the sense of immersion has a substantial impact on the user’s experience, which forced the team to make significant changes to the style of interaction experienced by the user. This section discusses features we employed to exploit and enhance the VR experience as well as interaction changes we introduced for VR.

VR Model Features

It is natural to wander close to the form in VR. But going too close makes the viewer cross-eyed, and going through the virtual object surface destroys the illusion of reality. A spherical cutter feature used by the viewer, which in effect cuts holes in a solid VR environment, overcomes this by reducing horn radiiuses around the cutter. The cutter center has the strongest reduction; horn regions are completely removed. A cutter on the headset clears the form ahead of the user. Another cutter on a controller allows the user to carve out forms, revealing their internal structure (Fig. 7). Cutters help to create a good experience; users clear space around them in dense, jungle-like 3D scenes.

Tightly constrained animation on the wall and audio parameters provide variety without destroying the form. Direct controller interaction modifies geometry, lights, etc., and mutation is triggered by a button press. Non-VR rendering uses traditional fixed three-point lighting. In VR we attach lights to the user’s headset (like a miner’s lamp) and to their hand controllers (like a torch flashlight); this increases immersion as a user’s movements cause moving shadows from their lights.
The team programmed additional effects to add life to the form; these effects operate autonomously without user interaction. *Pulse* modifies the radius along the horn with time, progressively moving along the main horn and into subhorns, giving the form a worm-like moving effect. *Breath* distorts the form by expanding the central region outward with time. Both effects add a visually pleasing continuous small-scale organic movement to the scene unaffected by the user's interaction with it.

VR gives a feeling of scale missing from other computer graphics. We exploit this by causing fairly quick changes of world scale (Alice effect [28])—shifting quickly from a standard 6m³ room to a large 60m³ room to a small 1m³ box, trapping the user's head in a tight space. This small-box effect requires a "quick out"; some users find it claustrophobic.

Complex feedback makes form and background merge, making 2D images confusing. VR 3D and motion help the brain resolve this confusion. The room environment was initially rectangular; distorting it using a superegg shape adds variety to the user's experience (Fig. 8). Flowing feedback in supereggs is so effective that we sometimes observe users to be closely studying the wall patterns while almost ignoring the main 3D form in the center.

Seeding feedback from the previous frame in VR makes head movement create nauseating image movement on the wall and leaves uninteresting feedback when one looks away from the form. To avoid this problem, we seed feedback in VR with an extra view from a relatively fixed camera. Sound is spatialized and related to the form in VR, particularly the correspondence of form size to overall pitch.

**Interaction in VR**

S implicity and discoverability are critical for interactive software in the exhibition environment, as many users have only a few minutes of interactive experience. This is especially true in VR, where facilitators cannot easily communicate with and help users. We (Putnam, Latham and S. Todd) conceived a companion work to *Mutator2* (*Mutator VR: Vortex* [29]) for VR with a simple interface.

Our VR exhibitions use an HTC Vive with two controllers. Figure 2 shows how controllers' buttons trigger various experiences. In our first VR exhibition, we found it difficult to explain the buttons to users and help users get the correct controller in the correct hand. This limited users' experience of the installation. We now use a piste of predefined effects assigned to the triggers, with detailed features available on other controller buttons. This allows users to have a full experience with almost no training and permits experimentation by experienced users. Piste trigger clicks quickly turn "bad" scenes into good ones.

Figure 2 shows the mapping of body positions to genes. Genes for the main horns of the form (black in Fig. 4) are controlled by users' arm movements. When a user moves their arms apart, individual stack genes change for all six main horns. Up-down movements bend these horns and in-out movements twist them. Thus these three movements map to 18 genes. Similarly, three degrees of freedom of red-controller rotation control genes for the four tail horns (red in Fig. 4; gray in print publication), affecting 12 genes overall. The green controller (left in Fig. 2) rotates the entire form.

This mapping is a key part of the interface that we are still adapting. Critically, the effect is intuitive and discoverable even though implementation details are not.

**Conclusions**

We discuss above how *Mutator2* brings an artistic gallery experience to today's interactive and VR world. A surreal balance of reality and unreality creates a surreal artistic impact, with a careful balance between artist-imposed constraints and freedom of user choice. The VR environment changes the experience and impacts the interactive interfaces. The procedural approach of *Mutator2* translates well to VR but requires an intuitive interface to foster a playful experience enhanced by VR and body tracking.

Looking forward, we plan to extend the system with multiple users in the same virtual space interacting with an experienced performer in that space. We will also bring the subjective mutation experience into the VR space, augmented by machine learning to focus mutation.
Acknowledgments

This work was partially conducted in the Digital Creativity Labs, with support from the Engineering and Physical Sciences Research Council, the Arts and Humanities Research Council and Innovate UK under grant number EP/M023265/1.

References and Notes

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Manuscript received 15 January 2019.

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