Eye Tracking as Interface for the Design of Generative Visual Forms and Patterns

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ABSTRACT
When working with generative systems, designers enter into a loop of discrete steps; external evaluations of the output feedback into the system, and new outputs are subsequently reevaluated. In such systems, interacting low level elements can engender a difficult to predict emergence of macro-level characteristics. Furthermore, the state space of some systems can be vast. Consequently, designers generally rely on trial-and-error, experience or intuition in selecting parameter values to develop the aesthetic aspects of their de- signs. We investigate an alternative means of exploring the state spaces of generative visual systems by using a gaze- contingent display. A user's gaze continuously controls and directs an evolution of visual forms and patterns on screen. As time progresses and the viewer and system remain coupled in this evolution, a population of generative artefacts tends towards an area of their state space that is 'of interest', as defined by the eye tracking data. The evaluation-feedback loop is continuous and uninterrupted, gaze the guiding feedback mechanism in the exploration of state space.

Categories and Subject Descriptors
F.1.2 [Computation by Abstract Devices]: Modes of Computation—Interactive and Reactive Computation ; H.1.2 [Models and Principles]: User/machine Systems—human information processing ; H.5.2 [Information Inter- faces and Presentation]: [Input devices and strategies, User-centered design]

General Terms
Design, Experimentation, Human Factors, Theory

Keywords
saliency, generative systems, digital morphogenesis, emergence, eye tracking, aesthetics, HCI, form finding

1. BACKGROUND

1.1 Generative Processes in Design
The use of generative processes for the discovery of novel forms and patterns is not uncommon to the practices of con- temporary artists, composers and designers. In architecture, 'morphogenetic design' [3] is a 'form finding' strategy where designers initiate (often biologically inspired) computational generative processes to yield novel forms or patterns. Such form finding includes a search through state-space for outputs matching specific design criteria. This search consists of a loop of discrete, temporally discontinuous steps as external evaluations feedback into the design of the form-generation processes. In contrast to more traditional methods of creation, such as using a paintbrush (where there is immediate sensory feedback to actions), here the designer's action- perception loop is discontinuous.

Appropriate parameters can be automatically arrived at with a computational evolutionary process, if a fitness function can be defined. In architecture, for instance, the selection of the 'fittest' can correspond to functional requirements such as structural integrity - essentially an optimistion problem. However, for the aesthetic dimension of their task, designers must use other means to find appropriate parameter values. This can be difficult when the systems are complex and the output is determined by numerous interconnected components; a small change in parameters can have difficult to predict consequences. Moreover design involves exploration and discovery; designers may not know a priori what the features of a desired output are.

1.2 Eye Tracking as Design Tool
Eye tracking data is often used as feedback to inform the designs of user interfaces, web pages, advertisments and products on the supermarket shelf. Additionally, there has been a considerable amount of research into using gaze tracking as a control interface [1]. Research on eye tracking in image search tasks suggests that information in gaze pat- terns can be used to make inferences about human interests [2]. Eye tracking as the interface to a genetic algorithmic process has also been explored [5]. In such work, one of a number of discrete stimuli is selected and these selections determine their evolution. This occurs in temporally discrete steps of selection and generation.

2. APPROACH
Instead of a design process with discrete, discontinuous steps of evaluation and feedback, our framework allows a continuous navigation of a generative system's state space. We use real-time eye tracking as the feedback mechanism to 'steer' morphogenetic processes, such that the user is in a structural coupling with the evolution of the processes. This is a variant on gaze-contingent methodology, which is used widely in visual perception research [1].

2.1 Design
Instances of a class of generative visual artefacts populate the screen. The output can either consist of individual distinct generative artefacts, or can be used to evolve textures that are the result of spatially overlapping entities. To increase variety, we apply noise to the parameter values: a process of

Predicting Perceptions: The 3rd International Conference on Appearance, 17-19 April, 2012, Edinburgh, UK. Conference Proceedings Publication ISBN: 978-1-4716-6869-2,Pages: 117-121

differentiation. The feedback from the eye tracker drives a process of integration, where the parametric variety of the output decreases. This leads to an emergence and maintenance of form and pattern, the user taking on the role of a designer engaged in 'form finding'.

2.1.1 Parameter Space

In the software each of the parameters of our generative output is represented as a two-dimensional plane, virtually existing behind the screen. Thus if our artefacts have three parameters, there are three planes. For an artefact at a given screen location, its rendering parameters are drawn from the parameter planes at the same screen position (Figure 1). The parameter planes contain floating point values between 0 and 1, however, using them can require a scaling to discrete integers (for instance the radius of a circle is measured in pixels). In these cases discrete boundaries appear in the visual output across the population of artefacts. Since edges and sudden changes are salient and attract the gaze, we apply a temporal blur to the output, turning the discrete changes into smooth transitions (Figure 2).
As parameters correspond to distinct aspects of a generative output, the same amount of change in different parameters can correspond to radically different levels of change in visual similarity. To address this we can apply distinct scaling functions to the mapping of our parameters.

2.1.2 Differentiation

When no gaze is detected, the parameters of our outputs smoothly and randomly traverse the state space. However this needs to be done in such way that neighbouring instances of the artefacts remain similar, and there are no sudden changes. To this end, three dimensional[1] Perlin noise [4] is used. Perlin noise is a method of efficiently generating graphical textures. Often used to model water, smoke and clouds, it is an elegant way to provide both tempo- rally and spatially continuous, yet random, values across a plane (Figure 3). This ensures that neighbouring instances of our artefacts are similar, and changes in parameter values are continuous (Figure 4). Additionally the Perlin noise algorithm relies on a deterministic pseudo-random number generator, allowing for the possibility to replay an exact evolution and repeat experiments.

2.1.3 Integration

The user's gaze affects the evolution of the parameter planes such that the population of artefacts over time tend towards areas of the state space that are 'of interest'. A running average of parameter values 'behind' the areas of the screen that have been gazed at in the recent past is continually calculated. The difference between the running average and the individual artefacts' parameters is used to construct a mask; the further a given artefact is from the running average, the more it is affected by noise. This has the effect of slowing and eventually freezing the evolution of the artefacts similar to the ones most looked at. Addition- ally the rolling average of parameter values 'gazed at' in the recent past exhort a weak 'gravitational pull' or bias in the evolution of the parameters.

2.2 Implementation

The eye tracking system used is Face Lab 5 by Seeing Machines[2] , a non-contact optical tracker. It sends in real-time the screen coordinates of the subject's gaze to the application driving the visual output, developed in C++.

3. POTENTIAL APPLICATIONS

With this setup, a user can consciously and proactively navigate through the state space of visual generative systems; volitional gaze a guiding mechanism in a discovery- orientated design process. Alternatively, subjects could passively survey the screen, their pre-conscious visual system determining the evolution of the scene. This can serve as a framework for research into the relationship between visual saliency, interest and, perhaps, aesthetic preference.

4. CONCLUSIONS

We outlined our design of an experimental setup that uses an eye tracker for the discovery and evolution of generative visual forms. This presentation will present some results of experiments carried out with this system.

5. ACKNOWLEDGMENTS

This work is supported by an EPSRC Doctoral Training Centre EP/G03723X/1 (HE), an EPSRC Leadership Fellowship EP/G007144/1 (MDP) and EPSRC IDyOM2 EP/H013059/1.

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[1] interpreted as two spatial dimensions and one temporal

[2] www.seeingmachines.com

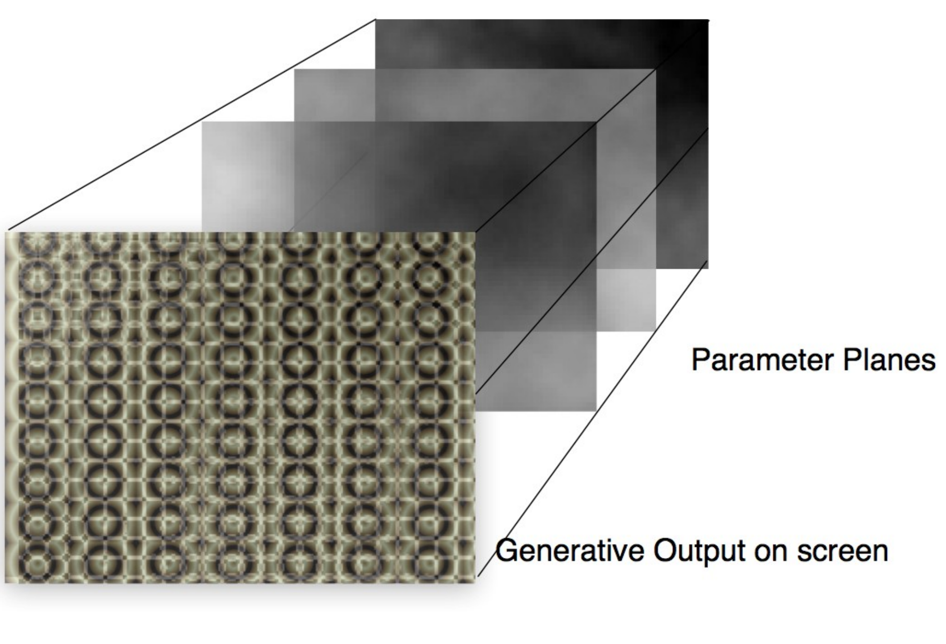

Figure 1: Parameter planes - values on planes map to parameters of artefacts on corresponding area of the screen

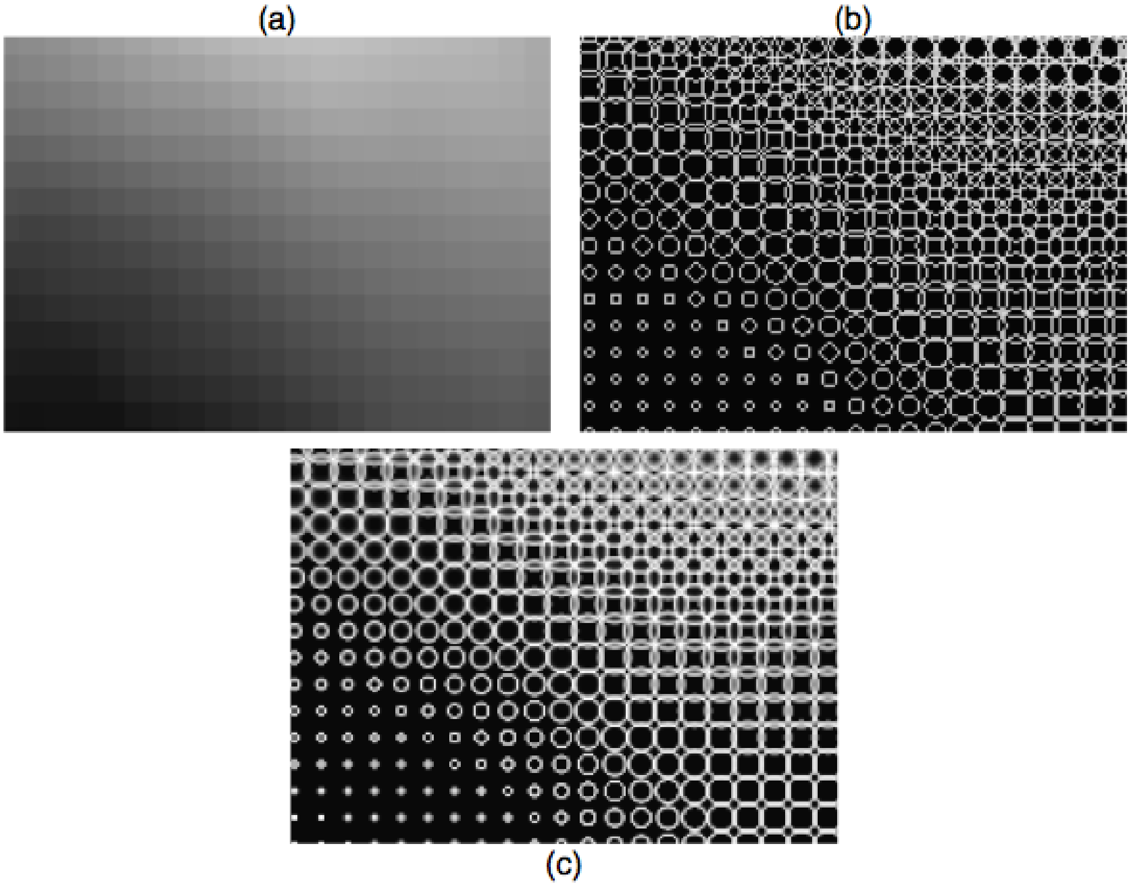

Figure 2: Changing parameter values(a) are mapped to a trivial output - the size of circles(b). Temporal blur is applied(c)

Predicting Perceptions: Proceedings of the 3rd International Conference on Appearance, pp. 117-121, Edinburgh, UK, ISBN 978-1-4716-6869-2, April 2012.

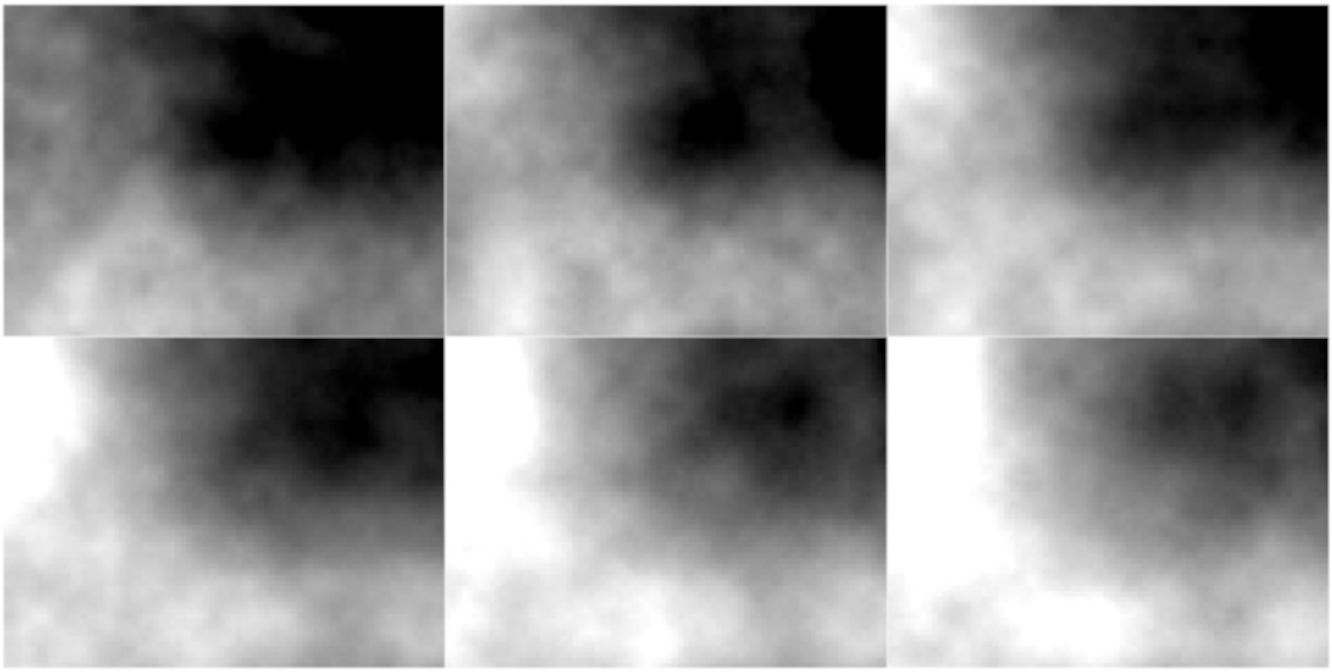

Figure 3: Perlin noise changing over a short period of time

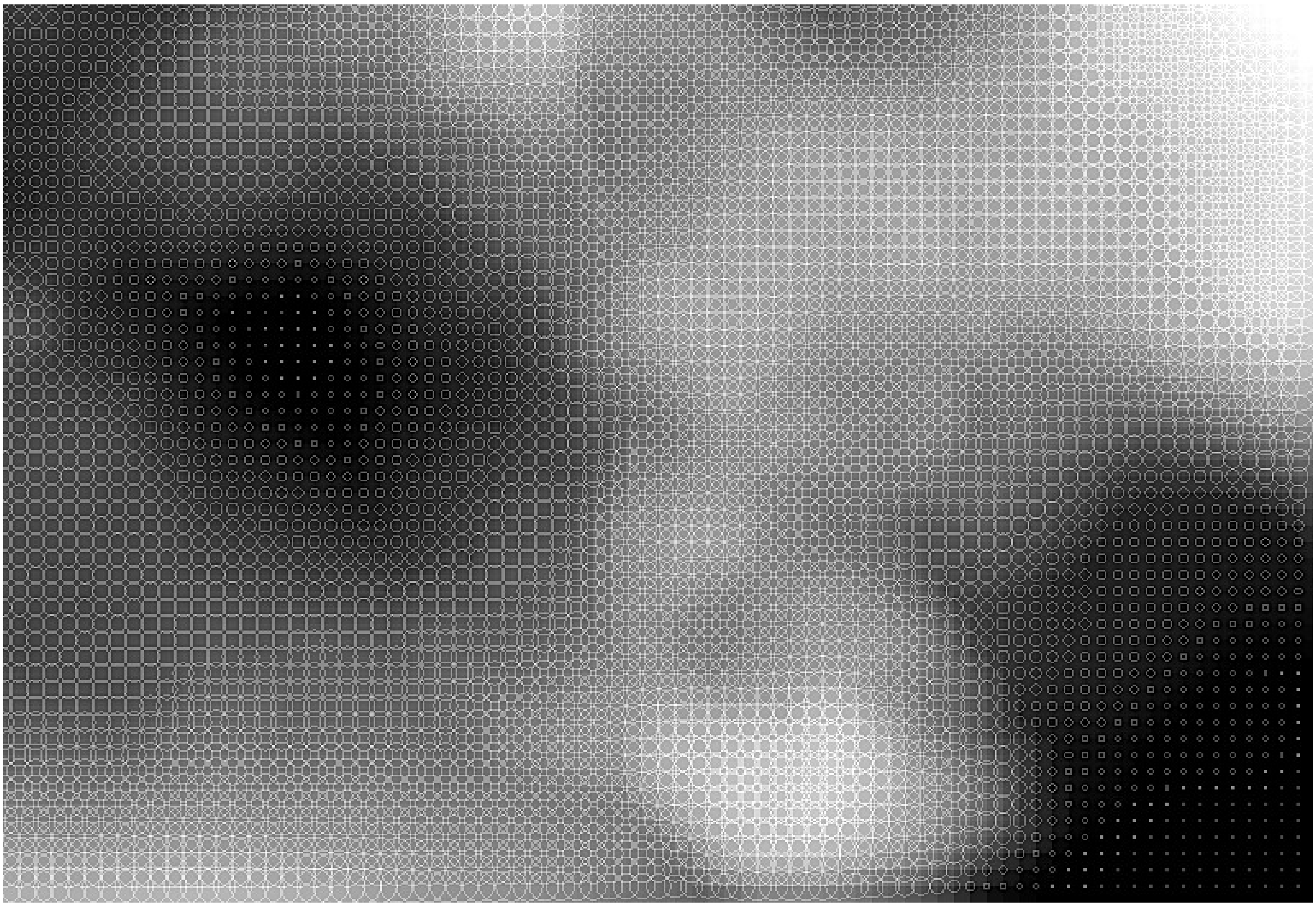

Figure 4: Parameter plane consisting of values from Perlin noise accumulated over time rendered as greyscale. This is overlaid by a trivial output - circles who's size is mapped to the parameter values