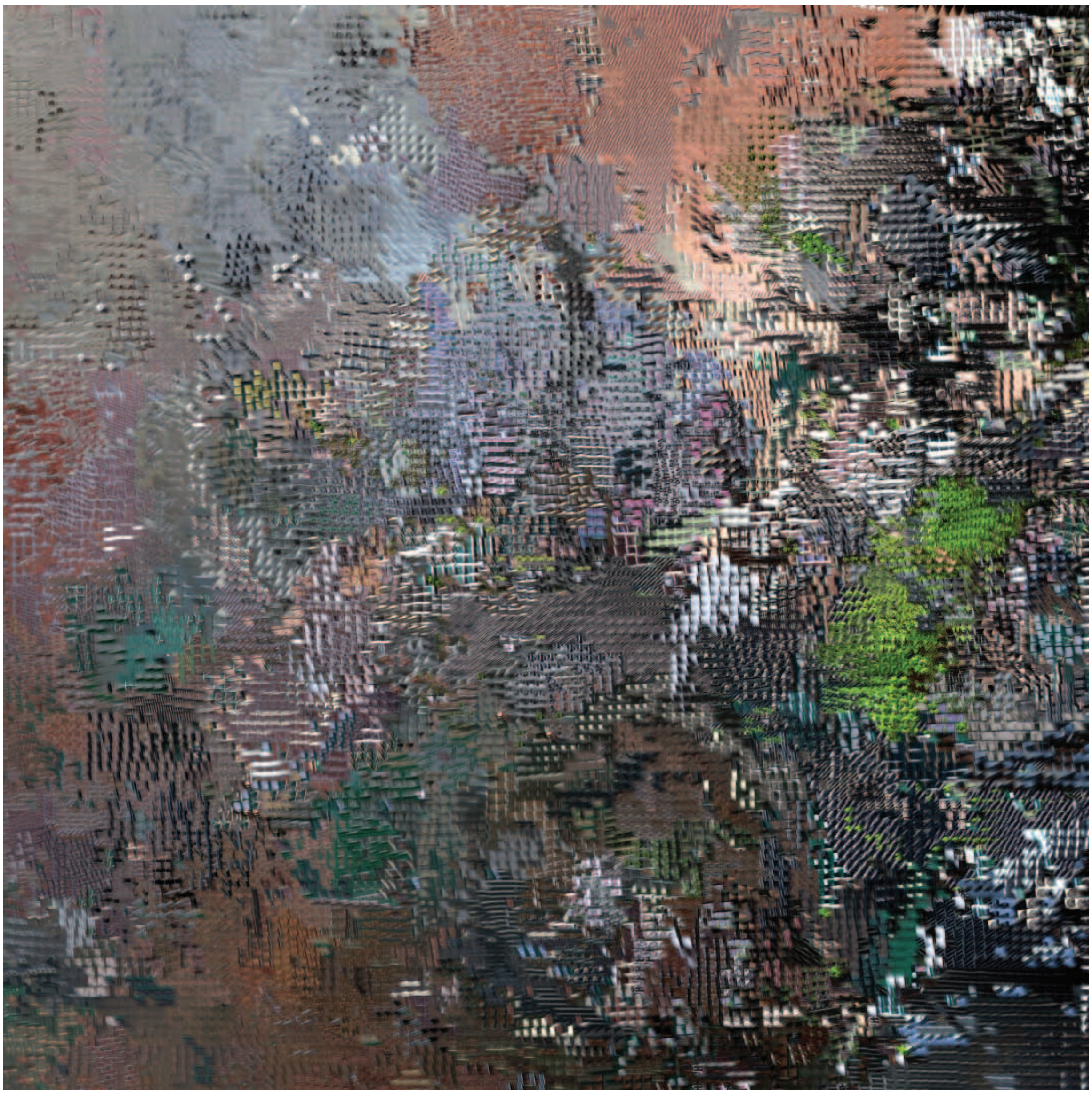

Context Machines: A Series of Situated and Self-Organizing Artworks

Benjamin David Robert Bogart
with Philippe Pasquier

ABSTRACT

The authors discuss the development of self-organizing artworks. *Context Machines* are a family of site-specific, conceptual and generative artworks that capture photographic images from their environment in the construction of creative compositions. *Resurfacing* produces interactive temporal landscapes from images captured over time. *Memory Association Machine's* free-associative process, modeled after Gabora's theory of creativity, traverses a self-organized map of images collected from the environment. In the *Dreaming Machine* installations, these free associations are framed as dreams. The self-organizing map is applied to thousands of images in *Self-Organized Landscapes*—high-resolution collages intended for print reproduction. *Context Machines* invite us to reconsider what is essentially human and to look at ourselves, and our world, anew.

1. Introduction

Context Machines are generative artworks, whose design is inspired by models of memory and creativity drawn from cognitive sciences. In a traditional artistic context, the artist works directly in the material that is presented to the audience. In generative art, the artist manifests the concept in a system whose output is presented to the audience. This is a process of metacreation: the building of systems that create media artifacts. Our development of *Context Machines* is manifest computationally and informed by cognitive models and theory, which are rarely exploited in generative art.

Our initial motivation leading to *Context Machines* is that their output be, to some degree, a surprise to us. Computational theories of complexity, emergence and nondeterminism contribute to processes that enable surprising results. The creative behavior of *Context Machines* is manifest in the generative representation presented to the audience. *Context Machines* are image-makers—but the process by which they generate images is more significant than the images themselves. Cohen describes the significance of cognitive processes in image-making:

> An image is a reference to some aspect of the world which contains within its own structure and in terms of its own structure a reference to the act of cognition which generated it. It must say, not that the world is like this, but that it was recognized to have been like this by the image-maker, who leaves behind this record: not of the world, but of the act [1].

Context Machines (presented chronologically in Fig. 1) share a number of core features: They all involve a computer-controlled camera, used to collect images of their visual context, and use computational methods to generate novel representations. *Resurfacing* [2] (see Section 3), developed by Bogart and Vakalis, is a precursor to the cognitively inspired *Context Machines* we have developed since. We discuss it to illustrate the transition between the overtly interactive artworks Bogart produced before 2006—where the viewer's behavior is integral to the work—and the emphasis on autonomy that informs our current cognitively oriented *Context Machines*.

Memory Association Machine [3] (Section 4) is an explicit application of self-organizing maps [4] (Section 2.4) and a simplification of Gabora's theory of creativity [5] (Section 2.3). In tandem, these processes provide a simplified "mind" for this machine, and our later projects depend on this central contribution. *Dreaming Machine #1* [6] and *Dreaming Machine #2* [7] (Section 5) use the same mechanism as *Memory Association Machine* in the construction of sequences of images that are framed as machine dreams. During the day, associations are initiated by images in the world, while at night they are randomly activated. *Self-Organized Landscapes* [8] (Section 6) are large and high-resolution print [9] collages that complement the *Dreaming Machine* installations. *Self-Organized Landscapes* far exceed screen resolution, and their structure reflects the self-organizing map's organization of thousands of pre-recorded images.

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Article Frontispiece. ***Self-Organized Landscape #32 (Millstream Courtyard, University of Limerick: Study From Video)*, Hong Kong, 2011. (© Benjamin David Robert Bogart)**

2. Background and Related Work

Context Machines are characterized by features consistent with conceptual, site-specific and generative art practices. The genesis of *Context Machines* is the result of motivational elements that initiate, and are transformed by, our production process. They also inform the use of Gabora's theory and self-organizing maps.

2.1. Artistic Practices

In conceptual art, the *idea* is of equal or greater importance compared with the *object*. For LeWitt, "Ideas can be works of art; they are in a chain of development that may eventually find some form. All ideas need not be made physical" [10]. Both conceptual and generative art have a strong emphasis on process over object. Conceptual art includes "instructional" works, in which the artist provides a recipe for the construction of an artwork rather than a finished piece. These works are highly analogous to generative artworks, wherein the artistic concept is encoded in software instructions and executed by

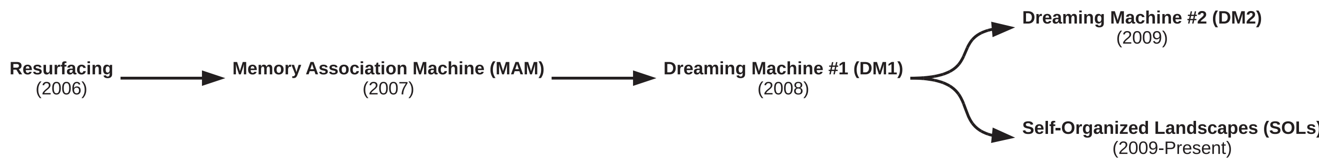


Fig. 1. The trajectory of *Context Machines* produced to date. (© Benjamin David Robert Bogart)

the computer. Site-specific art locates the meaning of an artwork in a specific social, historical or physical environment. For Kwon, a site-specific artwork gives "itself up to its environmental context, being formally determined or directed by it" [11]. *Context Machines* automate this task by literally capturing images of the environment and using them as raw material from which to generate their own representations. Generative art is a niche within the broader context of electronic media art, a contemporary art practice at the intersection of technology and cultural production. For Whitelaw, "New media art self-consciously reworks technology into culture, and rereads technology as culture." In his typology of a-life works, *Context Machines* can be considered hybrids of "Hardware" (where the importance of the physical world reflects the "movement of focus from inner to outer worlds") [12] and "Abstract Machines" (where there appears a "heightened attentiveness to form in itself and to processes of growth and transformation") [13]. The following motivational elements intersect with these artistic practices to varying degrees.

2.2. Motivation

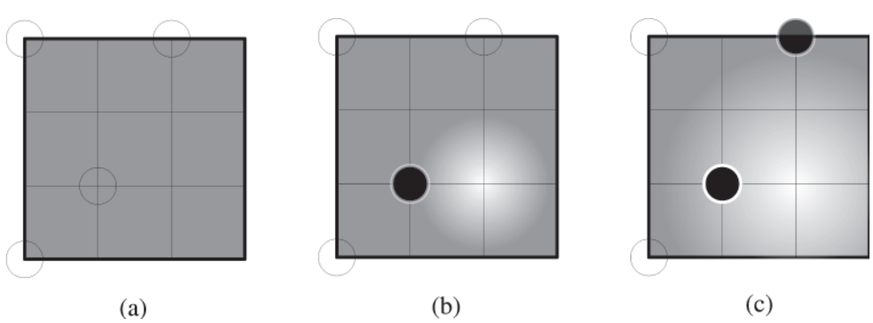
Our development of *Context Machines* was the result of a practice that is both driven and constrained by three primary motivational elements: (1) Our central drive in building *Context Machines* is an emphasis on autonomy—we expect some degree of surprise in their output. (2) The situated nature of *Context Machines* reflects an interest in embodiment, where internal processes are causally linked to the physical world. (3) Scientific models are used to enrich the meaning of the work through a rigorous linkage between the technical and the conceptual. These elements define a territory of enquiry we refine as the works are developed.

2.2.1. Autonomy

The artwork should relate itself to its context, without that relation being predetermined by the artist.

This is our central motivation and informs *Memory Association Machine*'s production and remains in the background of all *Context Machines*. The use of an "intentional stance" frames the work as an autonomous entity that is capable of forming a relation to its context, which includes the audience. In order to form such a relation, the artwork must be embodied—albeit in a simplistic sense: The world impacts the system through the images collected by the machine, while the artwork impacts the world through the subtle effect of its representation on the viewer. For example, a rich and complex representation may encourage viewers to approach the work, which would increase the number of images of people collected by the system. In addition is the aspect of surprise, where the machine's representation should, to some degree, appear independent of the intention of the artist. This interest in surprise is analogous to the interest in erasing the "artist's hand" [14] in traditional art. In illusionistic painting, the lack of visible brush strokes gives the viewer the impression that the work is magical and disconnected from the artist while simultaneously testifying to her skill. The creative behavior of the *Context Machines* provides a similar magical quality: "The signs of the will of a creator are sometimes less palpable in these objects than a manifestation of a 'will' of their own" [15].

Fig. 2. Differing degrees of activation of memory components resulting from a query: The open circles are locations where a memory component is stored, the radial gradient represents the query, and the opacity of the filled circles reflects their degree of activation. (© Benjamin David Robert Bogart)



2.2.2. Embodiment

The artwork is a "transforming mirror" [16] *that takes input from the world, processes it, and reflects it back into the world.*

The outward-looking nature of the *Context Machines* qualifies them as "transforming mirrors." In interactive artwork, the system's sensors are typically directed at the viewer. The "transforming mirror" reflects the viewer back at him- or herself. The output of the system provides an abstracted *portrait*—a transformed representation of the viewer's behavior. In contrast, the cameras used in the *Context Machines* do not focus on the viewer but reflect the whole visual context of the work back onto itself. The visual appearance of the work is then a *landscape*—a representation of place in space and time.

2.2.3 Modeling

The artist is more interested in the concrete process of doing rather than the abstract notion of representing.

This motivational element reflects a conception of computation as a link between concept and object. It presents a naïve dichotomy between doing and representing that has been questioned both historically and through our practice. From a materialist perspective, the act of representation is no less physical than any other process. The root of this dichotomy originates in the potential lack of continuity between material reality and artistic concept. The interest in *doing* is a desire for a rigorous integration of concept and material. This is consistent with the practice of Expressive AI [17] and is the foundation of the use of computational methods in our work, where the concept is encoded in software. In our current work, this interest in rigor leads to modeling, which bridges physicality and representation, and explains our interest in cognitive models. With the exception of *Resurfacing*, creative behavior is enabled by the explicit application of models from cognitive science and neurology. We have chosen models the properties of which align with our philosophical and artistic conception of the project and are appropriate for computational realization.

2.3. Cognitive Mechanisms Underlying the Creative Process

Gabora's conception of human creativity [18] is a core theoretical foundation of *Memory Association Machine* and *Dreaming Machines*. Gabora's theory focuses on the *generation* of creative ideas rather than their evaluation [19]. In essence, Gabora considers creative thinking a form of highly controlled association between memory components. These components are "micro-features" that define the qualities of memory. A creative thought process is composed of numerous cascades of these associations: A chain of many small, and perhaps obvious, associations can lead to extremely surprising and creative results.

The theory depends on three primary features: Human memory is content-addressable, distributed and sparse. These are features of the "conceptual space" (Fig. 2a)—a topologically organized space (gray plane) in which memory components (open circles) are situated. Memory components are content-addressable because they can be retrieved using their features rather than an arbitrary index.

A query, defined by the features of the item being searched for, is manifest in the activation of a location in the conceptual space (Fig. 2b). Memory components are activated inversely proportional to their distance from the query. The spread of activation allows the activation of multiple components that do not exactly match the features queried (Fig. 2c). The size and shape of the activation is controlled by conscious will. For Gabora, this is the cognitive manifestation of analytic and associative modes of thought. In analytic thinking, the activation function is small and tightly constrained in certain directions, allowing linear and rational links. Associative thinking results from a broader activation that spreads in multiple directions.

Memory components are not uni-

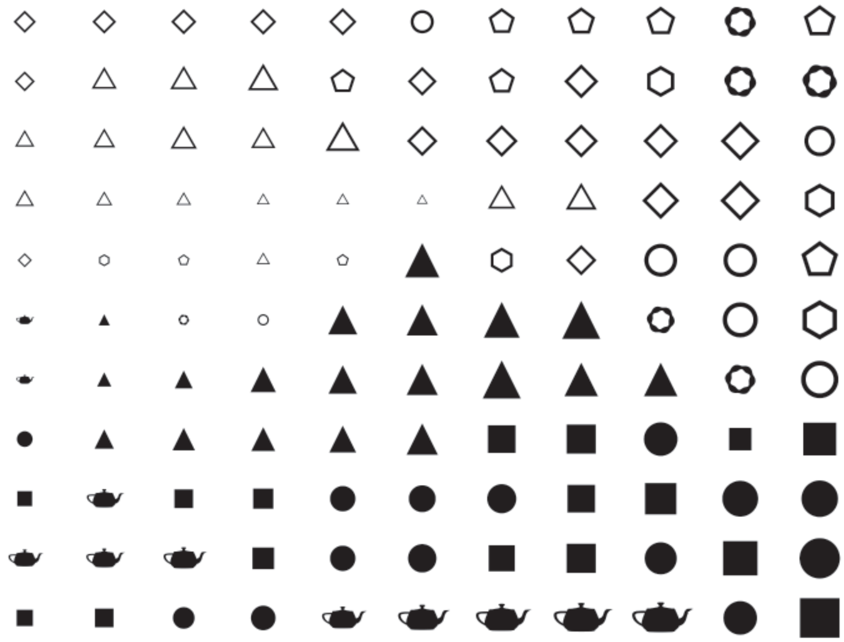
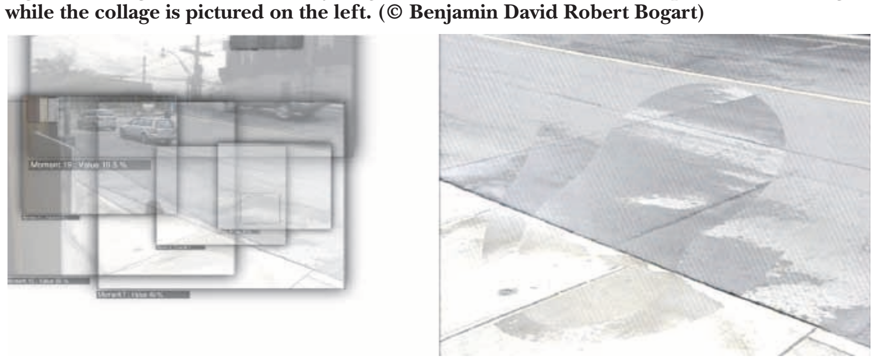


Fig. 3. A self-organizing map "feature-map" trained on images of black-and-white shapes. Note the clear boundary between filled and unfilled shapes. (© Benjamin David Robert Bogart)

Fig. 4. *Resurfacing* installation at the InterAccess Electronic Media Arts Centre in Toronto, 2006. (left) The screens and facade. (right) Interaction with the installation. (© Benjamin David Robert Bogart)

Fig. 5. Screen-grab details of *Resurfacing*. The interactive touchscreen is pictured on the right, while the collage is pictured on the left. (© Benjamin David Robert Bogart)



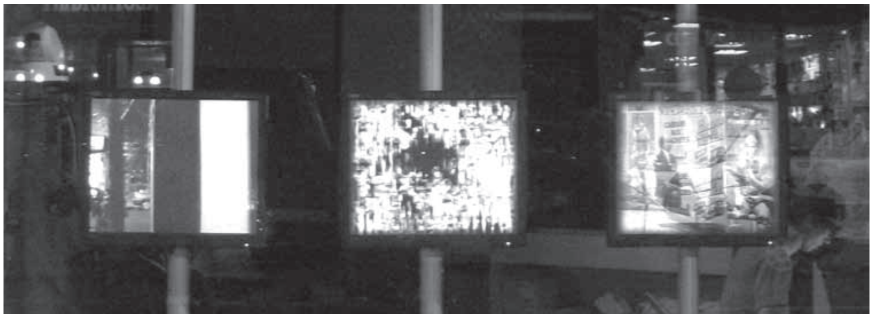


Fig. 6. Installation of *Memory Association Machine* at the Pure Data Convention in Montréal, 2007 (photographed during the night). (© Benjamin David Robert Bogart)

Fig. 7. *Memory Association Machine* photographed during the day. (© Benjamin David Robert Bogart)

formly distributed across the conceptual space, but form a sparse collection of islands of similarity where components can be associated using small activation functions. Islands can be bridged by large activation functions and correspond to "Eureka" moments.

2.4. Self-Organization

The ability of *Context Machines* to organize diverse visual images is enabled by the self-organizing map [20], which models a topological and content-addressable memory field analogous to Gabora's "conceptual space." The self-organizing map is an AI technique inspired by neurophysiology, composed of many simple units that work together to organize input patterns by similarity.

The result of a trained self-organizing map is a content-addressable "feature-map" that reflects the topology of the set of input patterns. The feature-map reflects the self-organizing map's structure—it is composed of a fixed number of units and often arranged in a two-dimensional grid. The feature-map associates input patterns with self-organizing map units such that similar patterns are associated with nearby units.

The self-organizing map is unsupervised—it does not require an external teacher but organizes input patterns based on the structure of those patterns alone. An example feature-map resulting from a set of images of various shapes at different scales is pictured in Fig. 3. The details of the self-organizing map, as it is implemented in *Memory Association Machine*, is discussed by Bogart [21].

2.5. Related Work

Context Machines are not unique in their use of computer-controlled cameras to capture images of the environment. A number of other art projects do so in order to create their own unique representations. David Rokeby's *Sorting Daemon* [22] and *Gathering* [23] are the most similar and use computer-controlled pan/tilt cameras to collect images of people. These images are sorted and scaled using a variety of algorithms to construct collages. These works are generative but do not make explicit use of cognitive models.

Byers et al. have constructed a "Robot Photographer" [24], a mobile robot that navigates through social gatherings in order to document participants via photographic snapshots. This project is meant to be overtly interactive: The viewer is expected to engage with the robot as if it were a human photographer. This project is technically similar to *Dreaming Machines,* as both use computer-controlled digital still cameras. While the Robot Photographer is oriented toward portrait photography, *Context Machines* use a multiplicity of images to create landscapes of various forms.

3. *Resurfacing*

Resurfacing [25] integrates both generative and interactive components and was produced before the cognitively oriented *Context Machines.* The artwork autonomously explores its visual context and collects images, which are stored in a navigable structure. The installation (Fig. 4) is composed of two screens housed in an architectural façade and a computer-controllable video camera mounted to collect images from outside the gallery. The system is initiated with 20 manually selected camera positions, indexed by the pan, tilt and zoom of the camera. Over the course of the installation, the camera continuously captures images as it cycles through these positions. The right screen (Fig. 5, right) shows a live video feed from the camera, while the left screen (Fig. 5, left) presents a collage of frames. The camera position (pan/tilt/zoom) is mapped to on-screen parameters (x/y/scale), resulting in an image that provides a slightly wider view that approximates, due to lens distortion and a lack of precision, the spatial relations between frames in the physical context. As the camera position changes, the collage is adjusted to match.

Sustained touch on the right screen results in a hole opening at the contact point that reveals corresponding images from earlier in time. As the viewer runs her fingers over the display, up to five layers of images, from the increasingly distant past, are shown. Each moment is annotated with a "value," calculated during each touch event, that reflects the relative number of contact events that occur while the moment is on screen. Each time a moment appears, its value is compared with a threshold. If the value is below the threshold, then a new random camera position will take its place during the next cycle. The value system is meant to rank moments by how much contact they receive, in order to replace low-value moments with new and potentially interesting ones.

Resurfacing aims to facilitate the viewer's examination of aspects of the world

Fig. 8. Sample of a feature-map generated by *Memory Association Machine*. (© Benjamin David Robert Bogart)

to which she may be habituated. The machine's gaze is strikingly different from that of a human. It tends to focus on visual items that are often ignored, providing a representational surface through which to encourage curiosity and exploration of the world.

4. *MEMORY ASSOCIATION MACHINE*

Memory Association Machine [26,27] (Figs 6 and 7) consists of three screens and a computer-controllable video camera. The left screen shows a live video feed from the camera, corresponding to the current stimulus. The middle screen (Fig. 8) presents the system's memory field [28]—the feature-map that results from the self-organizing map. The right screen presents *Memory Association Machine*'s associative sequence through collected images. Each screen presents one of the three processes that define *Memory Association Machine*'s behavior:

1. The *perception* process captures images from the visual context. The camera's gaze is driven by random pan/tilt values. For each associative sequence, the camera moves to a random position, and one image is captured. Each image is subsampled to 40×30 pixels and fed to the integration process as a vector of RGB values.
2. The *integration* process organizes captured images into the memory field, as enabled by the self-organizing map. The middle screen shows the memory field, where each node is represented by its corresponding image. To emphasize the content of the images—and de-emphasize their arrangement—Gaussianoid alpha channels are used (Fig. 8). The self-organizing map is continuously training as it attempts to learn the structure of the world. Due to the finite number of memory locations, and the complexity of the visual context, the self-organizing map will never converge at a stable topological representation that perfectly reflects the structure of the world.
3. The *association* process sequences images from memory and is enabled by an independent network of units that mirror the arrangement of units in the self-organizing map such that each unit is linked to a corresponding image in the memory field. When a new input stimulus is presented to the self-organizing map, the most similar image from memory is activated (presented on the right screen) and becomes the basis of a new associative sequence. The activation of an association unit results in the propagation of that activation to its neighbors to a lesser degree and after a random delay.

Figure 9a illustrates the overall pattern of activation: In Fig. 9b unit 17 is activated, to a degree represented by its shading. Two random directions are chosen, and the activation is propagated to neighbors between those two directions (units 11 and 12), to a lesser extent. Each of those units continues to propagate activation to an even lesser degree, as illustrated in Fig. 9c.

Each image is presented on screen with an opacity—and for a duration—proportional to the degree of activation. Every 12 seconds the camera chooses a new random direction, and a new image initiates another associative sequence. The length of these sequences is an emergent result of the interaction between the current image and the memory field. Reactivation is restricted by an inhibitory model that prevents already activated memories from being selected. Insufficient nighttime light restricts the duration for which *Memory Association Machine* is active. In order to continue to engage the audience, association units are randomly activated. This corresponds to the random activation of brain regions during dreaming, according to Hobson's model [29].

Memory Association Machine uses a novel combination of a self-organizing map and Gabora's theory of creativity to generate associative sequences of images. These images are collected from the visual context and represent the sum of the

Fig. 9. Propagation of activation signals resulting from associative sequences. (© Benjamin David Robert Bogart)

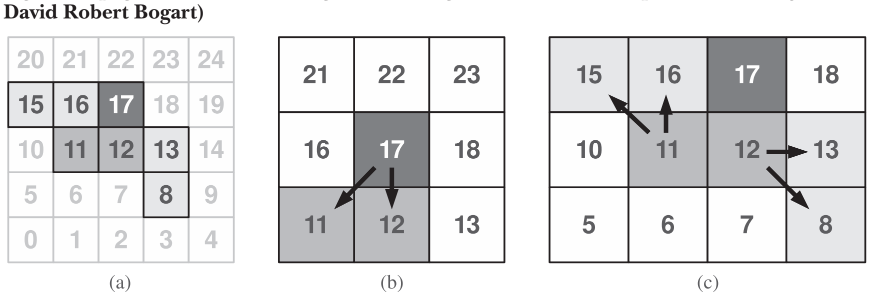


Fig. 10. ***Dreaming Machine #2*** **installation at Cinémathèque québécoise during the Elektra Festival, Montréal, 5–9 May 2010. (© Benjamin David Robert Bogart)**

system's experience. *Memory Association Machine*'s random nighttime associations inspired us to create *Dreaming Machines*, in which sequences are framed as machine dreams.

5. *Dreaming Machines #1* and *#2*

In *Dreaming Machine #1* [30] and *Dreaming Machine #2* [31] (Fig. 10) we refined the associative process initiated in *Memory Association Machine*. *Dreaming Machine #1* is a prototype and uses the same video camera as in *Memory Association Machine* installations. In *Dreaming Machine #2*, the video camera is replaced with a digital still camera on a computer-controllable pan/tilt mount. Both *Dreaming Machines* use a single screen that presents a fusion of the memory field and the associative sequence (Fig. 11). Both *Dreaming Machines* manifest the same process and differ only in hardware and installation details.

Fig. 11. ***Self-Organized Landscape #12 (View from Overpass: Study from Video)*****, Hong Kong, 2009. (© Benjamin David Robert Bogart)**

In an installation of *Dreaming Machine #2* for the Elektra festival [32], the camera was mounted on the second floor and looked over the street below (Fig. 10, right). The associative sequence was projected on a large display in the lobby (Fig. 10, left). The display shows the current activated memory in the center of the screen, surrounded by its eight immediate neighbors, all masked with Gaussianoid alpha channels and overlapping 50 percent (see Color Plate C No. 2).

Whereas the camera in *Memory Association Machine* was driven by random pan/tilt positions, the *Dreaming Machines* use a random walk to trace the camera over the visual field. In the *Dreaming Machines,* images are not sub-sampled and fed directly to the self-organizing map, but are abstracted into color histograms. The use of histograms simplifies the task of organizing images. As demonstrated in the *Self-Organized Landscapes* (Section 6), the histogram is sufficient when used on unconstrained real-world images.

In *Memory Association Machine,* memory activation is similar to dropping a pebble in a pond—energy is propagated in multiple directions. This results in an extremely dense and complex network of associations. In the *Dreaming Machines,* an activated memory propagates only to its most similar neighbor. The strength of the activation, manifested in opacity, decays inversely proportional to the degree of similarity between memories. The more similar the memories, the less the signal decays and the shorter the duration they are visible. The temporal inhibition used in *Memory Association Machine* is replaced with memory-specific inhibition: A memory will be activated only if its referent is not in a ring-buffer that stores previously activated memories. These refinements result in sequences that progress smoothly through individual associations [33].

The *Dreaming Machines* complete the contribution made in *Memory Association Machine* through a more faithful application of Gabora's theory. An aesthetic weakness in *Memory Association Machine*

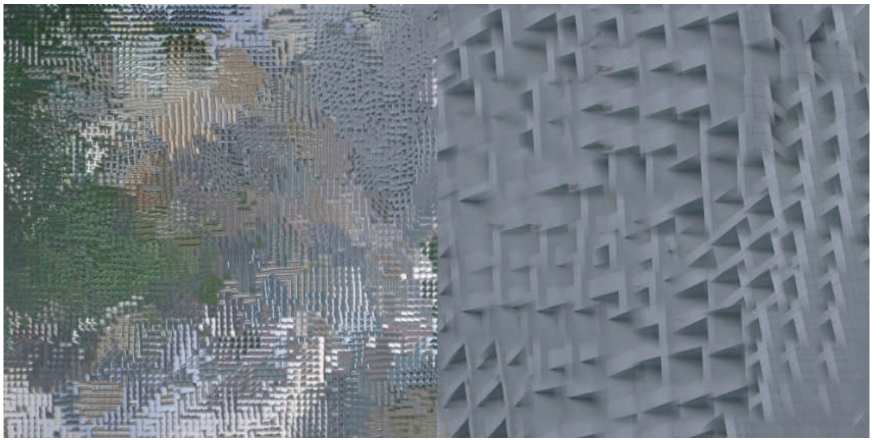


Fig. 12. (left) ***Self-Organized Landscape #6B (Self-Motivated Study),*** **Vancouver, 2009; (right) detail. (© Benjamin David Robert Bogart)**

and the *Dreaming Machines* is that the self-organizing maps never achieve a topological representation of the world.

6. *SELF-ORGANIZED LANDSCAPES*

In the series *Self-Organized Landscapes*, we applied the self-organizing map to a finite number of images, which allows *Self-Organized Landscapes* to more closely reflect the topology of input images. *Self-Organized Landscapes* have inherited many of the processes we used in the other projects discussed here, but in *Self-Organized Landscapes* they are applied in the creation of high-resolution print collages (Article Frontispiece, Figs 11 and 12).

Self-Organized Landscapes can be grouped into two categories: One uses the same computer-controlled digital still camera we used in *Dreaming Machine #2*, and the other uses frames captured on a hand-held high definition video camera. A 150×150 unit feature-map trained on approximately 10,000 images, captured using the still camera, is pictured in Fig. 12 [34]. *Self-Organized Landscapes* in this category are "self-motivated," in that an algorithm is used to generate pan/tilt instructions. The next position of the camera is determined from an analysis of five regions—the left, right, top and bottom edges and the middle—of the current image. A histogram of each edge region is compared to the middle histogram. If the difference between the middle and left histograms is greater than the difference between the middle and right, then the camera pans left, to a degree proportional to the difference. The same process is repeated for the tilt axis. This mechanism is meant to steer the camera toward areas that differ from the previous image.

A *Self-Organized Landscape* constructed from video frames is pictured in Fig. 11. The set of images tends to have less variance than those captured with the still camera because of the short duration required for capturing images (10,000 images can be captured in ~5 minutes of video, while the same number of images takes the still camera ~8 hours). The difference in variance leads to divergent aesthetics in the resulting landscapes. Video studies tend to have clearer cluster boundaries and appear more organic. In the *Self-Organized Landscapes* we have directly applied knowledge attained through the development of previous installations.

7. FUTURE WORK AND CONCLUSION

Our current research is focused on *Dreaming Machine #3*, which explicitly implements interrelated cognitive models of perception, memory and dreaming. *Self-Organized Landscapes* are large, topologically correct representations and are ideal "memory fields" for the associative process used in *Dreaming Machine #2,* resulting in *Dreams of Self-Organized Landscapes.*

Context Machines are artworks whose generative representational processes are inspired by images captured from their installation contexts. We have found few examples of generative artworks that are informed by cognitive models of creativity and create images from visual material collected from the contexts of their installation. These works encourage us to see the world anew through a reconsideration of art, perception, memory, creativity and dreams. The artwork is meant to be a public discursive interface for questions such as: What are crucial aspects of creativity and dreaming? Can these extend to non-human animals and machines? What aspects of mind are not represented in AI systems and cognitive models? What is lost if we accept strict scientific conceptions of mind? A machine that creates and dreams is a reflection of our (perhaps misguided) conceptions of ourselves.

Acknowledgments

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27. *Memory Association Machine* was originally titled *Self-Other Organizing Structure #1.*

28. This memory field results from a test installation and is composed of 12×12, rather than 20×20, units.

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33. See dream samples in supplementary material. A selection of dreams, exhibited at Transmediale: <http://www.ekran.org/ben/video/DM2-DreamSelection.mpg>.

34. The same image may appear in multiple locations in the collage.

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Environment 2.0

Guest Editor: Drew Hemment

In urban environments we are separated from the consequences of our actions as surely as the tarmac of the road cuts us off from the earth beneath. But between the cracks in the pavement, another world flourishes—local activism, recycling, environmental collectives, permaculture, urban gardening. Artistic and social projects can widen the cracks in the pavements. Such creative innovations might be artworks, social entrepreneurship, scientific intervention or innovations that harness everyday creativity.

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