Virtual Constructive Swarm Compositions and Inspirations

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Abstract. This work is an example of the interplay between computer-generated art work by a computer scientist and traditional paintings on canvas by an artist. We show that computer-generated swarm constructions can obtain great expressiveness and exhibit liveliness, rhythm, movement, tension, contrasts, organic looks, and rigid forms. These characteristics lend themselves to complement traditional paintings when swarm constructions are integrated into the according works. The interplay between computationally generated and traditional art is even furthered when artistic conceptualizations are governed by swarm constructions.

1 Introduction

When swarms were first modeled in the virtual realm in the form of flocking birds (boids) [12], spectators awed at animations of the interaction dynamics of flocking agents. Soon the cooperative swarm paradigm and the intrinsic dynamics of swarm models were transferred to other fields, most prominently those of artificial intelligence, where they became versatile optimizers [2, 9].

A typical example of swarm intelligence in nature are the stunning construction capabilities of insect societies. Ants, wasps, and termites intrigue with magnificent compositions made from leaves, mud, and sand. Models of these distributed, decentralized construction processes are able to reproduce those natural structures in virtual, computer-generated scenarios [13, 11, 16]. In the same context, *swarm grammars* have been shown to elegantly capture constructive swarm methods. Here the individuals flock like traditional boids [12, 8], but they also reproduce in accordance with a grammatical production system [14]. Swarm agents, as they split and specialize during the construction process, give rise to innovative and artistic structures [6, 15].

We have extended the swarm grammar concept by an event-driven rule application, thus creating a more versatile constructive swarm system. In Section 3 we show how constructions of this extended swarm model become part of traditionally crafted art works, thereby offering a complementary perspective. The interplay between computer-generated and human art is deepened when impressions of swarm constructions give rise to modern artworks in Section 4.

2 Related Work

In 1987 Craig Reynolds presented a computational model of swarms that exhibit natural flocking behavior [12]. An individual, or *boid*, accelerates according to its *flocking urges—separation:* heading away from the neighbors, *alignment:* adjusting one's velocity towards the neighbors, and *cohesion:* being attracted towards one's perceived neighbors. In later work, additional urges and specific configurations were introduced that result in diverse flocking formations such as 'V'-shaped formations [4] or line, circular and figure-eight patterns [8].

Emergent choreographic flocking of bio-inspired swarms have influenced many art works. While spontaneous creativity of swarms is reflected in many paintings [10], their potential to coordinate and to show surprising vividness is, for instance, applied in automatic and assisted music generation [1]. The same features render them ideal as interacting units of interactive swarm art installations [5] that exhilarate large audiences.

But a swarm's abilities can surpass choreographic flocking. For example, a very successful model suggests that termites, ants and wasps construct their nests in a step by step fashion according to stimuli in their nearby environment [2, 11]. Importantly, the construction is not driven by a blueprint or by explicit communication between the individuals. Instead, the configuration of the environment (*template*) determines the next steps of constructional swarm activity: A *stigmergic* chain-reaction is triggered where environmental changes lead to subsequent constructional efforts. Wasp nests emerge through *qualitative* or *discrete* stigmergy [7] depicting discrete stimuli that trigger activity. Termite mounds rise through *quantitative* stigmergy where the amount or intensity of a stimulus is reflected in the construction behavior [3].

In our constructive swarm model we embedded a generalized rule system into swarm grammars [6] to allow for stigmergic communication. Now, neighborhood stimuli, random events and timers determine the reproduction and construction activity of a swarm individual while flocking parameters determine the flight behavior in accordance with the boids model [12]. The swarm agent must know about the configuration of its offspring and about the attributes of its construction elements and templates. Hence, the genotype of an individual comprises the configuration parameters and reproduction rules of possible offspring and configurations of the construction elements and templates it can build.

3 Compositions

In this section, we present two compositions of traditional paintings and printed digital structures that were constructed by swarm grammars [6]. Figure 1(a) shows: [Generative], where desolate ambiance is reduced to its simplest form (20" x 26" Pencil, pencil crayon on Mayfair). Tension is built by swift vibrant strokes and radiant aggregations. The swarm construction placed at the bottom-right of the painting *bridges back and foreground* and strengthens the impression of *movement*. Figure 1(b) shows [A Splinter of Blue in a Sea of Red], a nonsensical piece based on rhythms (20" x 28" Gouache, watercolor, charcoal, transparent paper). Here, rhythmic themes are complemented by *wavelike* (center-right) and *circular* structures (bottom) that arose through dancing swarms. In both cases the embedded swarm constructions add *dynamics* to the paintings. The constructions leave the impression of vibrant or rhythmical movements because the lively building processes of the swarms are solidified in the respective sculptures.

The swarms utilized in the presented compositions were bred by interactive evolution: Upon the display of several phenotypes the breeder drove the evolutionary process by manual fitness assignment. The genotypical information comprised the flocking parameters, the attributes of the construction elements, and the grammatical reproduction rules of the swarm agents.


(a) (b)

Fig. 1. Compositions of printed computer-generated swarm constructions and brush work: (a) [Generative], (b) [A Splinter of Blue in a Sea of Red].

4 Inspirations

In the previous section swarm constructions solely complemented traditional art work. Now, digital swarm designs become the basis to inspire artistic studies. Thereby, the relationship between computer-generated and traditional art is emphasized.

Virtual constructive swarms were configured to serve loose artistic conceptions that resulted in swarm constructions (Fig. 2). These computer-generated constructions paved the way for further art work fleshed out by knives, pens and brushes (Fig. 3). In the following paragraph, we successively describe the pairs of swarm constructions depicted in Fig. 2 and inspired art works displayed in Fig. 3.

A steady trace of green spheres with regular branches creates the impression of an *organic structure* (Fig. 2(a)). The artistic realization extrapolates from organic matter towards human life and problems in our relationship with the environment: [Aftermath] (Fig. 3) is a study on the condition of human consumption (8” x 8” acrylic on matte board).

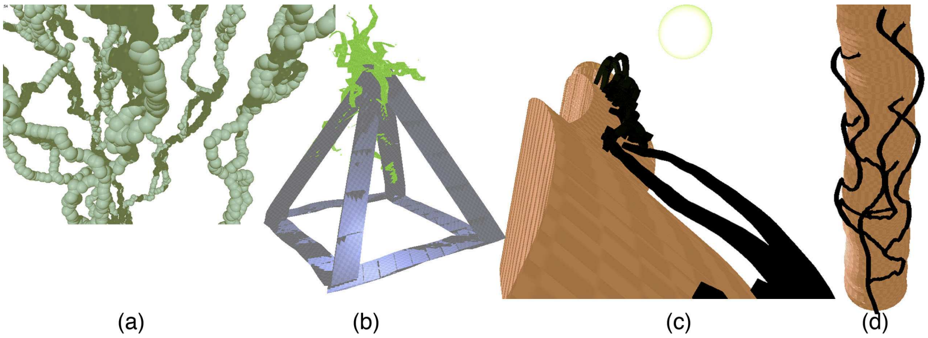

Fig. 2. Constructions of swarms programmed according to loose artistic conceptions. From left to right: (a) Branching constructions of spherical shapes, (b) a pyramidal construction with swarming agents in green, (c) and (d) a wave-like and a stem-like construction are outlined by a thin, black, branching thread of swarm agents.

The base of the pyramidal swarm construction (Fig. 2(b)) is *rigid* and shines in *cold, steel-blue* colors. In contrast, tentacle-forming swarms *wind* from its peak. The *explosive polarity* of the pyramid inspired the piece [Manifest] (Fig. 3) that places the swarm pyramid into a new context, in which unrequited thoughts seek ways to escape (12" x 24" black gesso, acrylic on Masonite). Painted layers were scratched away to reveal the raw Masonite surface. Soft swipes led to a semi-transparent reflection of the rigid pyramid foundation. Energetic cuts at the pyramid's top lend the painting real structure.

The intrinsic swarm dynamics and the *contrast* between *hard, structural manifestations* and *delicate outlines* (Fig. 2 (c) and (d)) are reflected in the remaining four pieces in Figure. 3. In [Skip Cross] a swarmette[1] makes a playful leap when facing a crossroad (8" x 16" acrylic on Masonite). The swarmette's flight is retraced with swift motions and underlined with an emphasis on positive and negative space. [Unravel] is the title of a piece where a Chinese calligraphic character reveals itself beneath a surface (8" x 8" ink on rice paper). The color themes and associated forms are directly inherited from the underlying swarm constructions. [Net Sky] inverts the predominance of the original swarm constructions: A web is woven in a *coordinated* fashion. The black threads *agglutinate* in front of dissolving purple and yellow clouds (8" x 10" acrylic on Masonite). In the first panel of the diptych [Outlining Blues] a distortion of the swarmettes formulates a Whale-like specimen as it swims in a peaceful surrounding. The second panel leaps backward in time and depicts first organisms coming into existence (both 12" x 24" oil paint and rusting agents on metal).

The presented works isolate and abstract from a variety of phenomena that materialize in swarm constructions, examples are: Organic looks (Aftermath, Outlining Blues), indications of lively movements (Manifest, Skip Cross), polarities and contrasts of shapes and looks (Manifest, Unravel, Net Sky), as well

[1] A swarmette is a swarm agent within our swarm grammar system.

Fig. 3. Swarm-inspired art — descriptions of the pieces are found in the text. Top-left to bottom-right: *Aftermath, Manifest, Skip Cross, Unravel, Net Sky,* Diptych: *Outlining Blues.*

as structural coalescence (Net Sky, Outlining Blues). Additionally, many of the presented pieces put an emphasis on spatial dimensionality — with an interplay of positive and negative space (Skip Cross), the elaboration on real structural depth (Aftermath), or via the creation of crinkly textures (Unravel).

5 Summary and Future Work

In many cases swarm constructions conserve the dynamical processes of their creation. Thus, swarm constructions show a remarkable variety of features that are interesting for artistic works. We have shown that rule-based virtual constructive swarms are capable to create structures that become part of compositions and inspire traditionally created art works. The characteristics of swarm constructions displayed by the presented art are hard to evaluate computationally in the sense of a 'fitness function'. In order to foster these qualities (such as vividness or coalescence) in constructive swarms, interactive evolution is an ideal approach. Therefore it would be interesting to render them the objectives of interactive evolutionary breeding — to maximize, for instance, vividness or coalescence. However, swarms could also develop diverse and innovative designs by themselves. As we have also demonstrated, instead of interactive supervision loose pre-defined constraints could drive purely non-human art.

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