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*Paper:* **Emerging Visual Structures from a Random Walker**

***Topic: Architecture***

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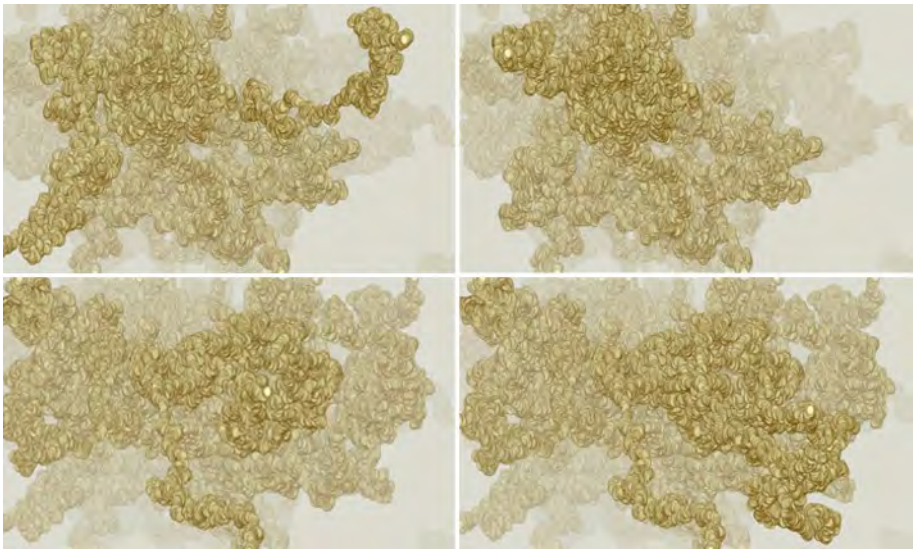
***Abstract:***
The present paper presents a one-agent based artificial system for generating visual structures that respond to known principles for organizing the visual field in art and design. The algorithm is meant to aid the artist in the process of generating a very large number of compositional variations that are impossible to produce by the human artist alone. The human intervention is limited to the selection of parameters in code before launching the system. The algorithm works independently in generating visual structures and interacts independently with elements that define the perceived dynamics of the emerging compositions. Variations of the algorithm allow the artist to interact with the working agent and contribute more actively in the process of positioning the emerging form clusters and introduce colour accents in the composition. However, apart from the initial selections of parameters, the algorithm is able to produce autonomously visual structures that are organized in compositions that are coherent from an artistic standpoint.
The system functions in the two dimensional field and it is based on a random walker algorithm working in tandem with a visual fader. This combination is meant to induce the feeling depth in the emerging visual compositions.
Considering the different degrees and the nature of artist's active involvement with the artificial system in the process of visual structure development, the paper analyzes the nature of the creative act in relation to the software based medium and the emerging notion of artificial creativity.



*Cluster of compositions sampled from the visual random walker, version 3.*

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[3] Shiffman, Daniel. 2012. *The Nature of Code: Simulating Natural Systems with Processing*. The Nature of Code 1st ed.

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# Emerging Visual Structures from a Random Walker

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**Abstract**

The present paper presents a single-agent based artificial system for generating visual structures that respond to known principles for organizing the visual field in art and design. The system is meant to aid the artist in the process of generating a very large number of compositional variations that are impossible to produce by the human artist alone. The human intervention is limited to the selection of parameters in code before launching the system. The system works independently in generating visual structures in interaction with elements that define the perceived dynamics of the emerging compositions. Variations of the basic algorithm through which the system is implemented allow the artist to interact with the working agent and contribute more actively in the process of positioning the emerging form clusters and introduce colour accents in the composition. However, apart from the initial selections of parameters, the system is able to produce autonomously visual structures organized in compositions that are coherent from an artistic standpoint.
The system functions in the two dimensional space and it is based on a random walker algorithm working in tandem with a visual fader. This combination is meant to induce a feeling of depth in the emerging visual compositions.
Considering the different degrees and the nature of artist's active involvement with the artificial system in the process of visual structure development, the paper discusses the shift in our understanding of the creative act in relation to the software based artistic medium and the emerging new notion of artificial creativity in the contemporary digital art practices.

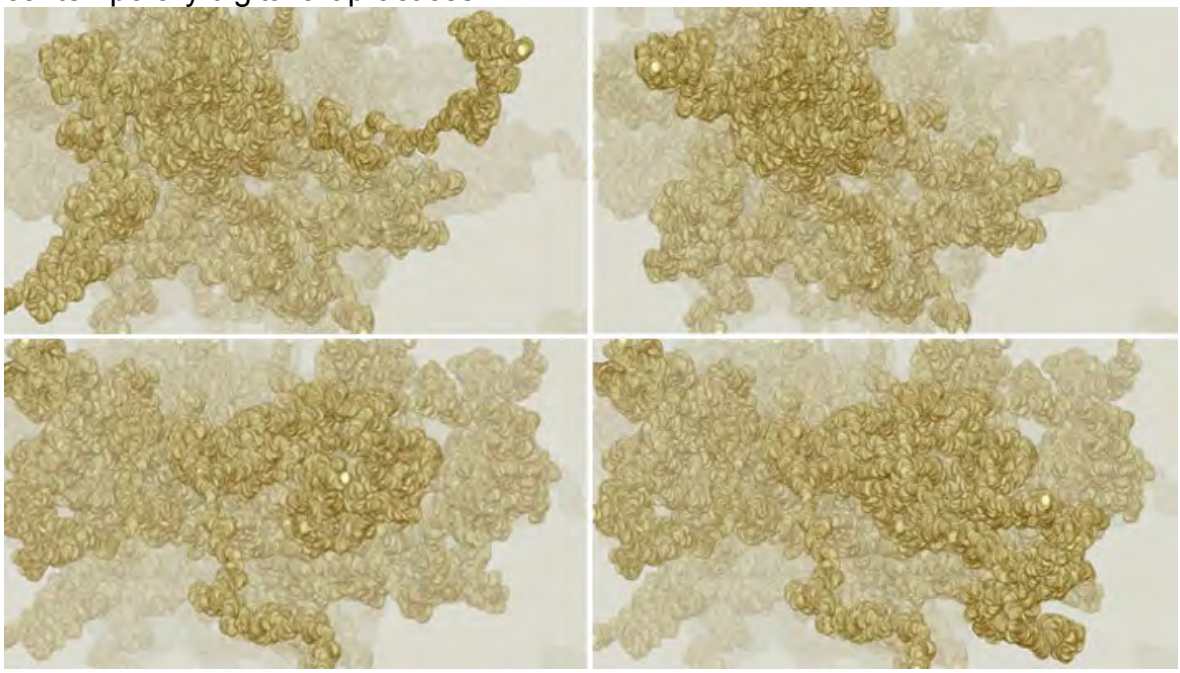

*Figure 1. Compositions sampled from the Visual Random Walker, version 3.*

## 1. Introduction and Background

This section explains what has inspired the use of random walks as the basis for the development of visual structures in artificial systems.

The random walk algorithms are related to the analysis of particle movements in physical systems with the first published observations on Brownian movement of particles in liquids made by Robert Brown in 1827 [12] and the first formalized description of diffusion laws provided by Einstein [2], [12]. Einstein's diffusion laws show dependencies of the particles' movements on such parameters as temperature, viscosity, number of particles, and gas constant. Eventually, the random walks emerged as an adequate model of diffusion with the random walker taking at each discrete moment in time a unit size step along the positive or negative direction of one axis in n-dimensional spaces. The probability to take any of these directions at each moment in time is of value 1/(2n).

The classic random walk algorithm can be applied to different spaces and depending on the nature of these spaces and of the objects associated with them, the meaning of the walker's steps and paths may change. Other extensions of the classical random walker are based on different methods of random selection of the direction at each moment in time and various implementations of these lead to significant changes in the general behaviour of the random walker.

In spite of its apparent simplicity, the random walker provides a starting point for simulating natural movement in artificial systems. The artistic community has shown an increasing interest in creating such simulations of the natural world using software for the development of applications to serve visual explorations of new art forms based in software [3], [8], [9], [10].

The visual constructor algorithm described in this paper is based on a discrete classical random walker moving in the bi-dimensional space of the picture plane [4], [8], [11], [13]. The output is concretized in graphical forms structured in comprehensive abstract designs. The continuous Brownian motion of the random walker underlies the permanent changes that reconstruct these designs into emerging new ones [5]. While the laws of diffusion relate to physical properties that influence the Brownian motion in physical systems, our algorithm takes into consideration changes in variables that affect the visual properties of the emerging visual designs. This paper presents changes brought into a classical random walker algorithm so that the new algorithm underlies the generative development process of abstract designs on continuous basis or until ended by the user.

## 2. The Visual Constructor Algorithm

This section describes the artistic and engineering thinking underlying the behaviour of the single random walker agent so that in time it generates multiple and varied visual compositions that are coherent from a visual design standpoint.

### 2.1. Brief Summary and Main Goals of the Visual Constructor

The goal of the algorithm at the basis of the artificial constructor of visual designs is to organize the bi-dimensional structures generated by the random walker in the visual field in accordance with recognized principles and rules of visual composition [14]. It captures in the same time the nature of the human designers' loose approach and unpredictable decisions that seem to deny such principles and rules. In addition, our visual constructor algorithm aims to create a feeling of depth and induce the illusion of volumetric definition while working on a bi-dimensional surface.

Considering that the random walker is in fact a model of Brownian movement, it is expected that the emerging visual structures (Figures 1-3 and Figure 5) remind to a certain degree of natural structures formed in fluids or gas like, for example, clusters of matter in the cosmic space (Figure 4).

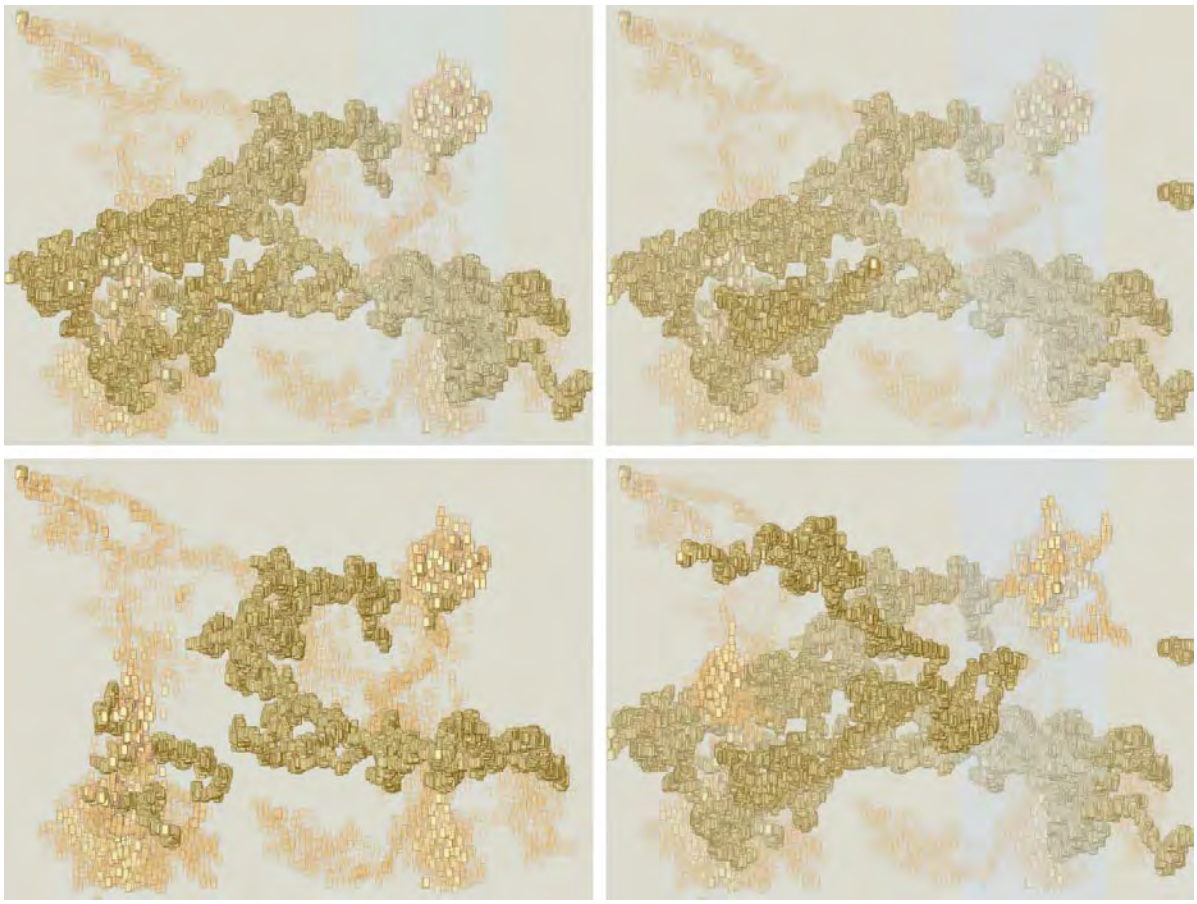

*Figure 2. Compositions sampled from the Visual Random Walker, version 8-5.*

*Figure 3. Compositions sampled from the Visual Random Walker, version 7-2*

(a) (b)

*Figure 4. Clusters of particles and matter in the cosmic space:*

(a) Jet in the Carina Nebula taken with Hubble's WFC3 detector – copyright: NASA, ESA, and A. Nota (STScI/ESA) (copyright: NASA, ESA, and A. Nota (STScI/ESA) (http://hubblesite.org/gallery/album/galaxy/pr2005035a/)

(b) "The intense outpouring of radiation from the central star cluster NGC 346 is sculpting the gas and dust in this region of space, located 210,000 light-years away in the Small Magellanic Cloud" – copyright: NASA, ESA, and A. Nota (STScI/ESA) (http://hubblesite.org/gallery/album/galaxy/pr2005035a/).

Starting from these general goals, the algorithm develops compositions on a continuous basis and in this sense it is a typical example of generative art. The visual output is of slightly unequal aesthetic value throughout the development process. This is due to the fact that the random walker moves in very small steps and the process of building structures in such small increments takes some time until new forms emerge. However, in time, the process always leads towards meaningful visual compositions.

The emerging forms are of such complexity as to make almost impossible the repetition of the emerging forms. This complexity is what makes possible the generation of new non-repetitive compositions on a continuous basis. However, although the development of forms through very small increments in hundreds of thousands or millions of steps may easily lead to visual overload, the visual fader module incorporated in the algorithm always resolves this problem by gradually sending in the far background the older complex form and refreshing the field where younger forms develop.

Considering these, the algorithm empowers the artist with the ability to work with a level of form complexity that cannot be achieved by human means alone and, therefore, providing a new platform for artistic exploration.

Some variations of the algorithm allow human aided development of the visual structures. The artist can introduce colour accents and can reposition the random walker. This allows the artist to intervene interactively and direct the process of structure formation in a drawing process based on the moving agent. Although this form of kinetic drawing is an important aspect of the algorithm, the present paper mostly focuses on the autonomous random walker as a generator of visual designs.

### 2.2. The Basic Algorithm

As mentioned in the introductory section, the visual constructor is an adaptation of the classical random walker algorithm with changes meant to produce meaningful visual output in the random walker's space, which, in our case, is the picture plane. The proposed system builds visual structures from traces left by a geometrical random walker. The algorithm is based on a classical discrete random walk in two dimensions [8, 1-4], [13, 39-58] and it is implemented with the Processing programming language [7], [8].

At each discrete moment in time, the agent may choose with equal probability to move in the positive or negative direction along the x or y axis. There is an equal probability distribution of chances to take a step in any one of the four directions. Because of the small step size and the even probability distribution, the agent moves at least for some time in a limited area and the traces of its random walk always cluster to some degree in that area creating the appearance of a larger complex form.

Starting from these basic elements of the algorithm, controlling the emerging designs requires the analysis of the correlations between the following aspects: (a) the geometric shape of the random walker; (b) the size and the proportional relationships between the geometric shape of the agent and the frame of reference; (c) the structure of the more complex forms resulting from the basic shape of the walker; (d) the distribution of forms within the pictorial field; (e) the texture, concentration, and contrast within the emerging forms and within the frame; (f) the illusion of depth. By controlling these aspects we aim to embed into the algorithm a generative system of visual organization for the emerging abstract designs. We discuss below how these aspects are handled in the visual constructor algorithm.

### 2.3. Building Form and Structure

The random walker algorithm continuously moves around the geometrical shape of the agent. We consider the basic shape of the agent to be the unit form from which the design is composed through various operations. Due to the intrinsic nature of the random walker algorithm, the most extensively applied operations to the unit form are translation in very small increments, repetition, overlapping and occlusion. All aspects of the emerging designs are depending on the results of these operations.

A number of geometric shapes were tested for the random walker, but the best visual results have been obtained with the simplest forms like ellipses, circles, squares or rectangles. This is because the shape of the random walker provides the basic unit from which larger forms are built through overlapping, repetition, irregular radiation, and gradation as the random walker moves around in small incremental steps.

The proportional relationship between the size of the frame of reference and the size of visual walker is important for the visual output. A number of tests showed that very small unit forms produce better visual results.

### 2.4. Creating Texture

The repetitions generate larger forms bearing a texturized appearance due to embedded repetitive traces of the geometric unit form. Several types of repetition occur as the walker moves around: repetition of size, repetition of colour and repetition of texture.

Considering that the unit form is small in size in the basic algorithm, we might expect that the multiple repetitions enumerated above would produce a rather uniform texture in the picture plane. However, depending on the extent to which the agent keeps moving in a given area, the resulting texture can be more or less spread out and more or less dense producing a certain degree of texture modulation that might bring interest in the composition.

### 2.5. Creating the Appearance Volume and Space

Although modulated texture alone may provide the basis for the emerging designs, the purpose of the algorithm is to base the design in forms with volumetric character and the entire composition to provide an overall feeling of depth. The spatial illusion is achieved by implementing a fading module working at local and global levels to create geometric and aerial perspective.

At local level, we can distance forms in depth by accompanying the repetition of the unit form with overlapping and occlusion at each step taken by the random walker. This creates the illusion that there is spatial distance between the repetitive unit forms and that the form that overlaps another comes closer to the viewer's eyes than the form that is partially covered. This system works if adequate correlation is ensured between the size of the unit form and the size of the random walker's step.

If the size of the random walker is larger than half of any of the height or width of the unit form, than overlapping cannot be achieved, in particular in the first phases of the random walker algorithm. In this situation, when the agent moves one step, this translates the form far enough from the previous position so that the form at the new location doesn't overlap with its previous trace. The two forms seem to be on the same flat surface of the picture plane and no illusion of distance in perspective is created.

Therefore, in order to create the illusion of depth, a condition is to keep the step size to a maximum value that is smaller than the minimum between the half of the width and the half of the height of the random walker. Satisfying this condition will ensure producing the feeling of depth through overlapping and occlusion of the unit form.
Aerial perspective al local level is obtained based on a certain degree of transparency of the unit forms. Overlaps with previous traces of the random walker often fade the traces left behind and make the more recent traces seem closer to the viewer.

At global level, the fading function is set into action by various interactions of the

random walker with the frame of reference. When such events occur, the fader will diminish contrast for all form generated up to the occurrence of the current event. New forms are drawn with much more contrast on top of the previous one creating the feeling of aerial perspective.
Apart from the role in creating aerial perspective, the fading modules has a role in diminishing the visual overload that unavoidably occurs through the development process.

### 2.6. Floating Structures

The compositions generated by the visual constructors have a general appearance of aquatic or fluid spaces populated by floating structures (see Figures 1-3, and 5). As mentioned in paragraph 2.1, this an expected result considering that the random walker algorithms are originated in studies of Brownian movement of particles in fluids.

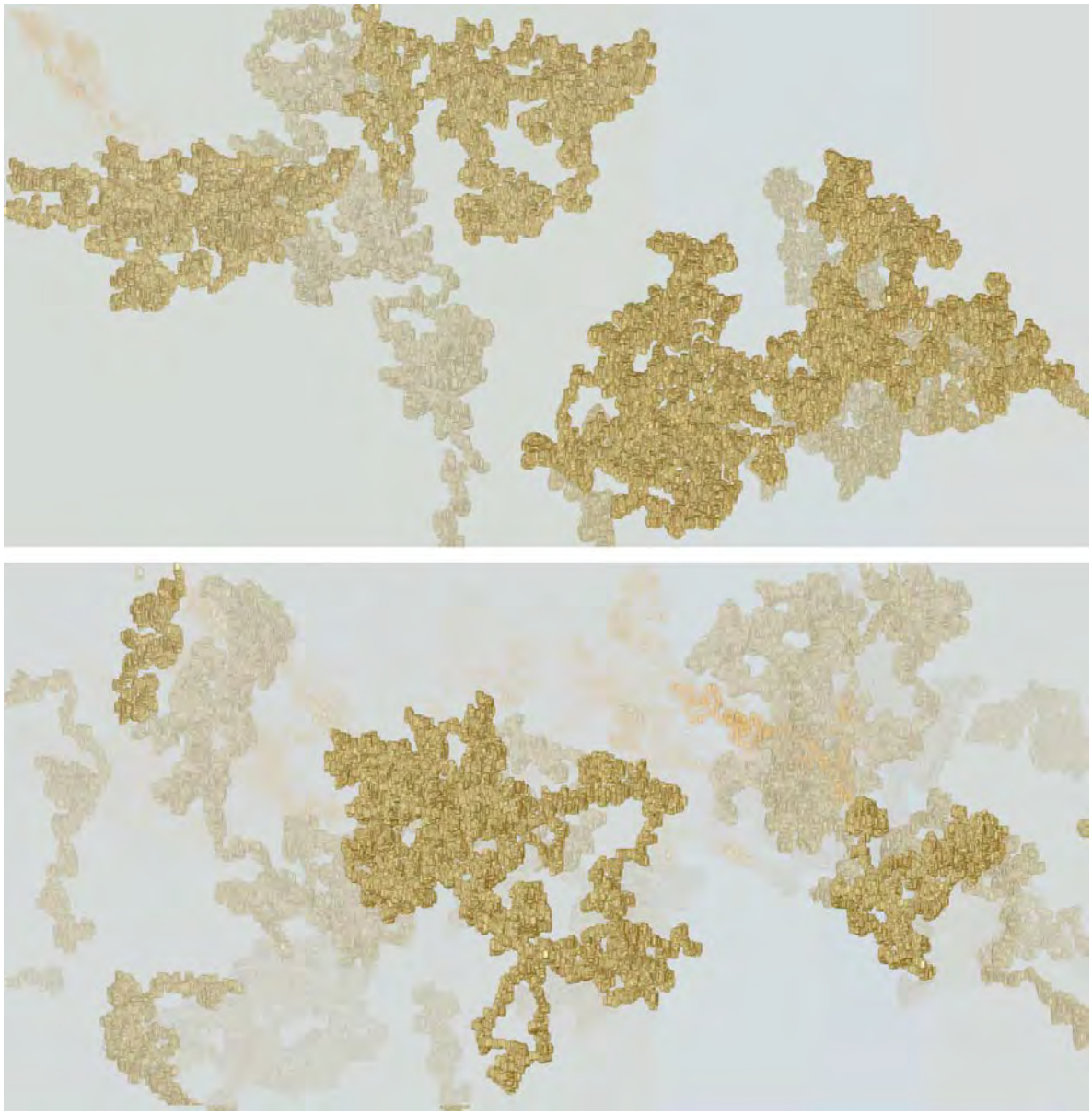

*Figure 5. Compositions sampled from the Visual Random Walker, version 8-3b*

This opens the possibility of further developments based on the implementation of agent interactions with various fields of visual tension in the picture plane [1] or by associating a physics engine to the algorithm so that the movement of the random walker is affected by such factors as gravitation, friction, and other simulations of natural forces.

## 3. The Artist and the Autonomous Visual Constructor

When discussing the autonomy of the Visual Constructor in the development process, the question of what is the role of the artist as a creator is naturally raised. Although this may provide the grounds for extensive analysis, we point out only several aspects that may clarify the problem in the case of the visual constructor algorithm presented in the current paper.

First, the visual constructor is created by the artist in a manner that allows comparison with the traditional artist using a medium to unexpected results. In the case of the visual constructor, the medium is the software and a classical algorithms that simulates some aspect of the real world: the Brownian movement of particles in fluids. The artist's adaptation of the algorithm is what makes the random walker a developer of visual designs.

The most significant aspect is that the artist is distanced from the creative process during the actual generation of the compositions. The system, once designed and tested, can autonomously produce a very large number of visual compositions which cannot be fully predicted and which are of extensive variety. The artist has an active role developing the concept of the artificial system and building the system in software. Once the system is launched, it works on its own.

Considering these, we conclude that we assist to a new emerging role of the artist in the creation process. The hand-eye coordination in the production of the work of art is removed. Instead, the actual production of the work is the result of an artificial system designed by artist. The artist becomes a system designer and the output, even in its unpredictable results, is the result of this design.

The proposed system also allows bringing back the role of hand-eye coordination and direct participation in the entire production of the artwork through the interactive version of the system.

The proposed system allows the co-existence of both models of the artist as system designer and the artist engaged in the entire production through kinetic drawing.

## 4. Conclusion

It is interesting to point out the emerging new forms of art production shifting the artist from the studio based environment into a software development process. The paper presents such a system providing a medium for the production of art where the creative process is fully preceding the effective development of the visual

compositions, but also allows the flexibility to intervene in the composition development through direct interaction with the system.

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