Chapter 6

Structure in Dynamic Media

6.1 Overview

The production of image from code was one of the first major challenges to early computer artists and scientists. Once this barrier was overcome artists began to explore a range of topics exposed by the use of digital technology. Languages for graphics focused on the production of the image using complex algorithms to produce dynamic content. Low-level languages such as Processing and Max/MSP provide a means to create basic shapes and forms while leaving the behaviour to be determined by an artist-programmer, while high level environments such as Houdini, Maya, and Xfrog offer a range of structures including particles, fluids, and L-systems (trees). LUNA was designed specifically to allow artists to remix different dynamic, autonomous structures and behaviours in an interactive environment.

Jörg Schirra observes a difference between the structure of image as a set of pixels and the structures found *within* the image, that is its content [Schirra, 2005] [1]. Abstract structures for content include basic primitives such as lines and curves. Harold Cohen proposes that the content of an image may be defined through art-making as a set of underlying rule-based activities which derive from the nature of cognition. Cohen's AARON, software designed to draw scenes of computer generated characters, is a system for determining the placement of line based on a set of rules, and therefore informs the content of the image through such rules.[Cohen, 1979]

This chapter is concerned with several dimensions related to the content of the image in media art. One dimension which will be explored is the nature of the rules which determine the placement of forms and shapes. Structure, in three dimensions, creates the appearance of surface and volume, so another axis for creative freedom resides in the materiality of the surface. Finally, the content of an image need not be generated by a set of rules, and might also come from hand drawn figures, or content borrowed from other sources, i.e. photography or collage. This use of content from the real world, whether it is drawn by an artist or taken from nature, is yet another choice available to the artist. The ideal scenario for creative tools for media artists would allow the exploration of each of these ideas. The objects currently found in LUNA were chosen to represent points along these dimensions to show that this kind of bricolage is possible at an abstract level in a digital environment.

[1] A structuralist argument may also define content as the values of each image pixel, but this perspective avoids the organization of pixels into groups such as lines, curves and forms which I consider here.

6.2 Behaviour, Dynamics, Autonomy

The rules for determining the placement, style, and orientation of lines, curves, and forms can be exceedingly complex. Lev Manovich uses the word complex to describe his experience of contemporary digital media in contrast to abstract minimalism of the preceeding era:

> "What is important is that having realized the limits of linear top-down models and reductionism, we are prepared to embrace a very different approach, one that looks at complexity not as a nuisance which needs to be quickly reduced to simple elements and rules, but instead as the source of life.. I am now finally ready to name the larger paradigm I see behind the visual diversity of this practice. This paradigm is complexity." [Manovich, 2007]

Setting up a duality between movements of abstraction and complexity in art creates several problems, however. First, this opposition avoids the fact that work of the Russian Constructivists, such as Malevich's Supremus No. 18, are both abstract and complex. This image, showing a detailed and subtle arrangement of lines and rectangles, was created after Malevich's reductionist period [Gray, 1962], so Malevich was aware of the reductive possibilities of abstract forms while simultaneously engaging in them as a multitude. Second, the source of the complex image in new media extends in part from early experiments in artificial life. The scientists who explored this field, including Alan Turing, John Von Neumann and John Conway, found that very simple rules could lead to complicated structures, thus complexity may reside only at a particular level. The problem is that the term complexity can be applied to such a wide range of human experiences despite the fact that in some cases very simple or abstract ideas underlying these experiences are present simultaneously, and that certain aspects of an image may be complex (e.g. placement) while others may not (e.g. form). Art of nearly any period may be described as complex in some sense. In what *way* is something complex?

A number of terms have been used by media artists to more precisely define types of digital art, which may be viewed as an evolving taxonomy. 'Functional' in computer science refers to that which is based on a set of rules, but may conflict with "serving a useful purpose". 'Autonomous' forms are capable of independent action, such as self-motion and self-reproduction, while 'Generative' art is capable of creating new structures and may or may not also be autonomous. 'Organic' forms are higher order structures which grow, change, or appear like those in nature. 'Behavioural' objects may be said to *act* on other objects, which implies a connotation toward human cognition. The term 'Computable' expresses that which can be decided by rules using a machine, and appears to cover all of these domains of media art, but has the essential drawback that we do not know if all organic, behavioural or autonomous objects in nature are also computable. I prefer the term 'Dynamic', as it expresses the idea that something is in *motion.* Even if the image itself is static, all media art is dynamic in the sense that something in the external world, a device, computer or kinetic object, is or was *changing*, that is acting on its own in the world. This concept of externalized change is new to art, since prior to the 20th century most art was created by ideas expressed through the human body.

To consider the content of media art in more detail involves looking at ideas which have motivated it. One possible starting point can be found in the science of *dynamic* *systems*. Edward Lorentz, Henri Poincare, and Benoit Mandelbrot explored iterative and non-linear systems in nature, leading to fractal and chaos theory. James Gleick collects and summarizes these ideas in the book *Chaos* [Gleick, 1987]. The term chaos itself is interesting as it expresses that which is beyond formal understanding. In a literal sense such systems can only be approximated with numerical methods since they general defy analytic solutions:

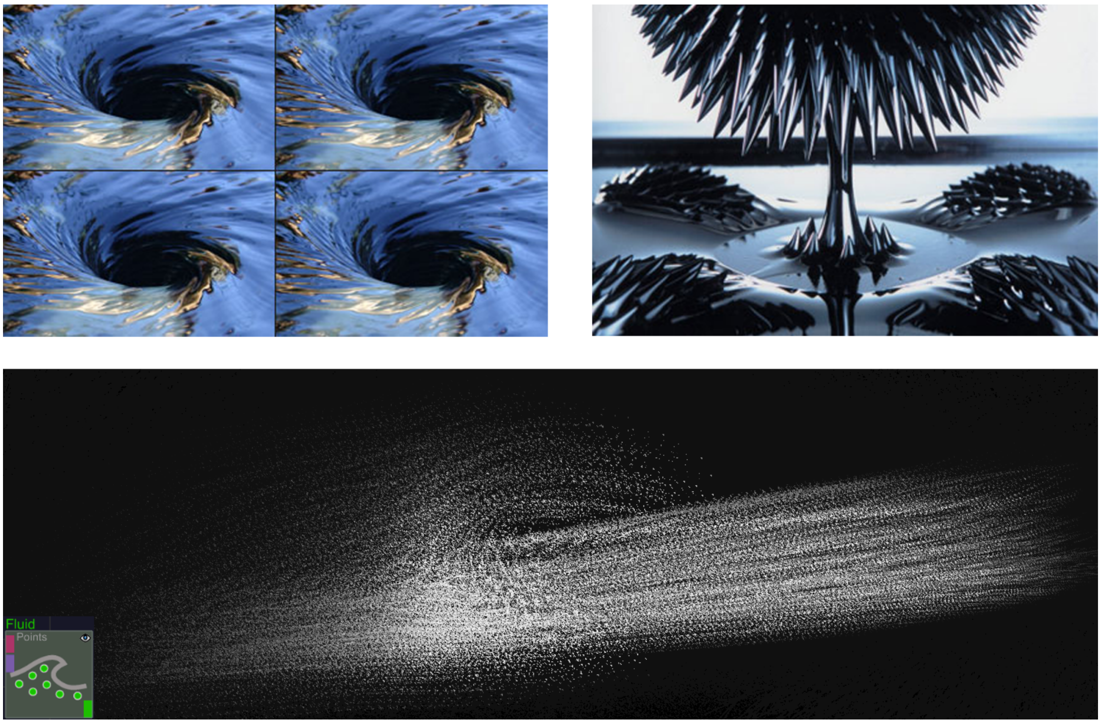


Figure 6.1: Fluid systems generate chaotic motions with vortices by Ned Kahn (top left), ferrofluids by Sachiko Kodama (top right), and waves by LUNA (bottom).

"Chaos is the irregular, unpredictable behaviour of deterministic, nonlinear dynamical systems." Roderick Jensen, Yale University. [Gleick, 1987]

A particular kind of non-linear dynamic system is the motion of fluids. While the science of fluids dates back to ancient history (Archimedes studied fluid mechanics), artists have explored irregular patterns in fluids as a form of beauty. Ned Khan uses architectural and sculptural elements, in a systematic way, to visually expose the flow of real wind and water [Mather, 2006]. Sachiko Kodama and Minako Takeno look at the dynamics of ferrofluids[2] in the work *Protrude Flow*, 2001. The most interest aspect of these works are the motions created by non-linear systems. LUNA allows artists to explore this motion through simulated fluids, a component in the system which embodies the rules that govern fluid dynamics, Figure 6.1. The fact that these systems are chaotic invites creative experimentation, since the variety of motions they produce can never be exhausted, an experience described by Kant as the ‘mathematical sublime’.

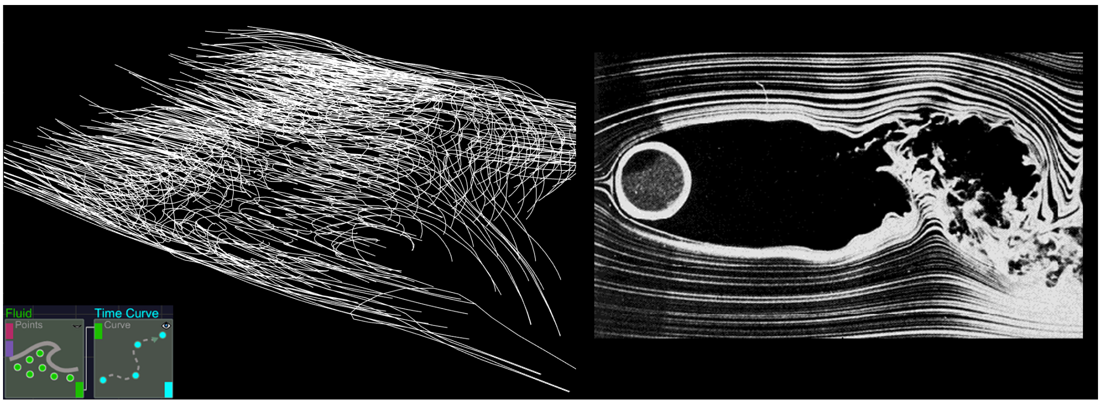


Figure 6.2

From a creative perspective, what is interesting about LUNA is its ability to easily combine fluids with other systems, to interact with or reveal this motion in unique ways.

[2] Fluids with magentic particles suspended in them

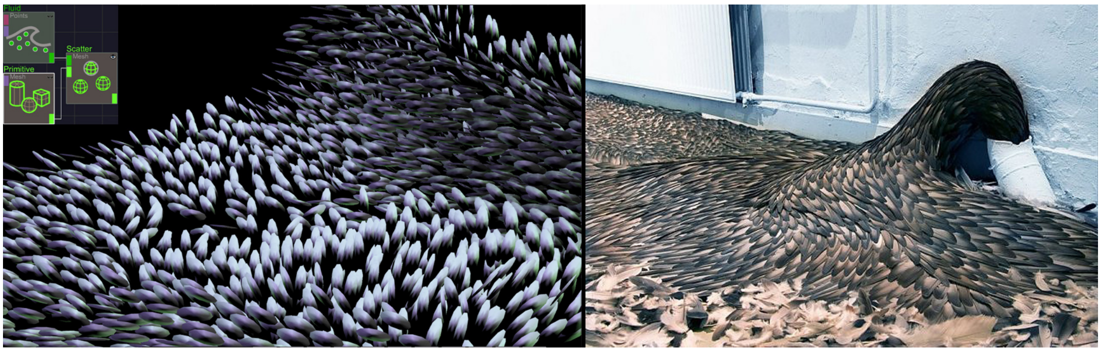


Figure 6.3

In 1961, Asher Shapiro developed a thirty nine video series on the mechanics of fluids for the National Committee for Fluid Mechanics Films, an educational institution to promote understanding of science [Shapiro, 1961]. One particular film, Flow Visualization, shows how helium bubbles suspended in a fluid can be used to *see* how the fluid moves over time, Figure 6.2. In a similar way, connecting the Fluid node to a Time Curve node allows the path of wave to be revealed. Kate MccGwire, in *Sluice* (2009), arranges feathers along the possible path of fluids in city landscapes. Although many software frameworks only allow fluids to appear as liquid surfaces, this kind of aesthetic is possible in LUNA by connecting the Fluid node, and a mesh describing any object, into a Scatter node which places the object at each point in the fluid. While LUNA is implicitly a simulation, these kinds of experiments can be performed with literally five or fewer mouse motions used to connect up the tiles. These rearrangements are similar to the work of the bricoleur, since they consist of a playful arrangement of the *connections* between found objects (found by the user), except that the objects themselves are dynamic systems.

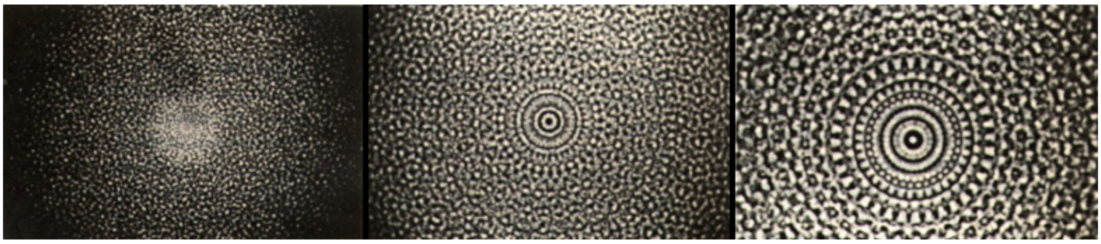


Figure 6.4: *Lapis*, John Whitney. 1967

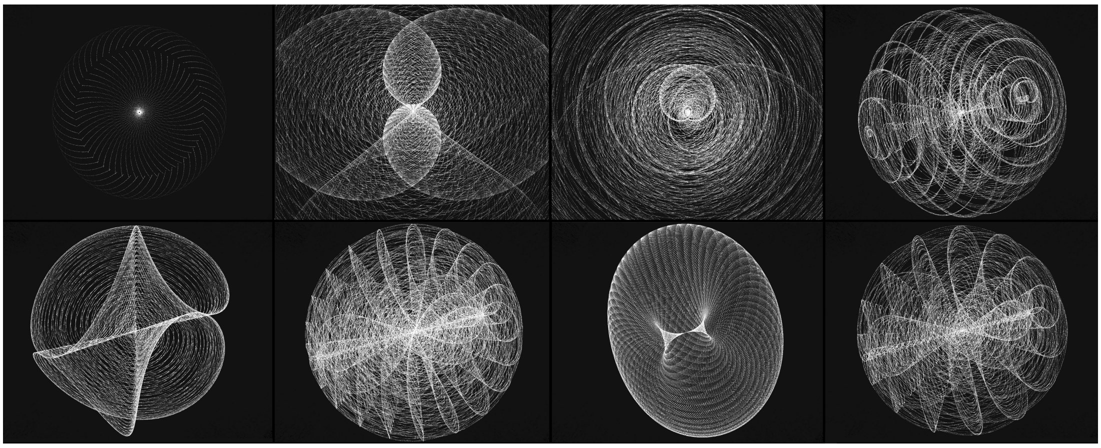


Figure 6.5: *Spira*, R.C. Hoetzlein. 2010. Created in LUNA.

Other disciplines have looked at motion in different ways. In music, the study of sound waves lead to ideas of frequency and phase in oscillations, while oscillations (tones) taken together form harmonics. John Whitney began looking at these dynamics visually using an oscilloscope, an instrument which measures waves in electronic signals [Russet and Starr, 1976]. Eventually, through a grant with IBM, Whitney found that computers could be used to directly study these patterns, Figure 6.4. In figure 6.5 images entitled *Spira* were created with LUNA using the Sinusoid object implementing a similar kind of behaviour. The Sinusoid object was created to show that these dynamics are possible using the same grammar as physical systems such as fluids, while a more complete language for harmonics would require a much larger set of other nodes which could be added to the system in the future. Square waves, sin waves, sawtooth waves, and filters which are found in music synthesis, might be added to the Function and Audio media types in LUNA.

Reflecting on motion it is understandable that structuralism, the idea that hidden rules determine the form of objects, would be extended from the art object to a way of looking at the natural world as many of these ideas came from scientists who were looking at nature themselves. John von Neumann, the first to consider if machines could self-reproduce, started out looking at how natural processes such as self-replication could be embodied in machines [Wainwright, 1974]. Once this was demonstrated in John Conway's Game of Life it was a natural inversion to consider that perhaps nature itself could also be described by similar rules [Levy, 1992]. A number of scientists began exploring processes for describing nature via rule-based systems, with great success. Craig Reynolds created a system for simulating the motion of birds [Reynolds, 1987], while William Reeves developed a way of representing fuzzy objects like fire and clouds [Reeves, 1983]. In LUNA, Reeves fuzzy objects are implemented as a particle system tile. A question persists for structuralism, which is whether or not all image making can be explained as a set of rule-generating behaviours? If so, then all that remains is to discover more of these rules. If not, then what about images makes them unique. This may be more of a question regarding natural reality, since any image is a picture of some reality. This issue will be revisited in the next section.

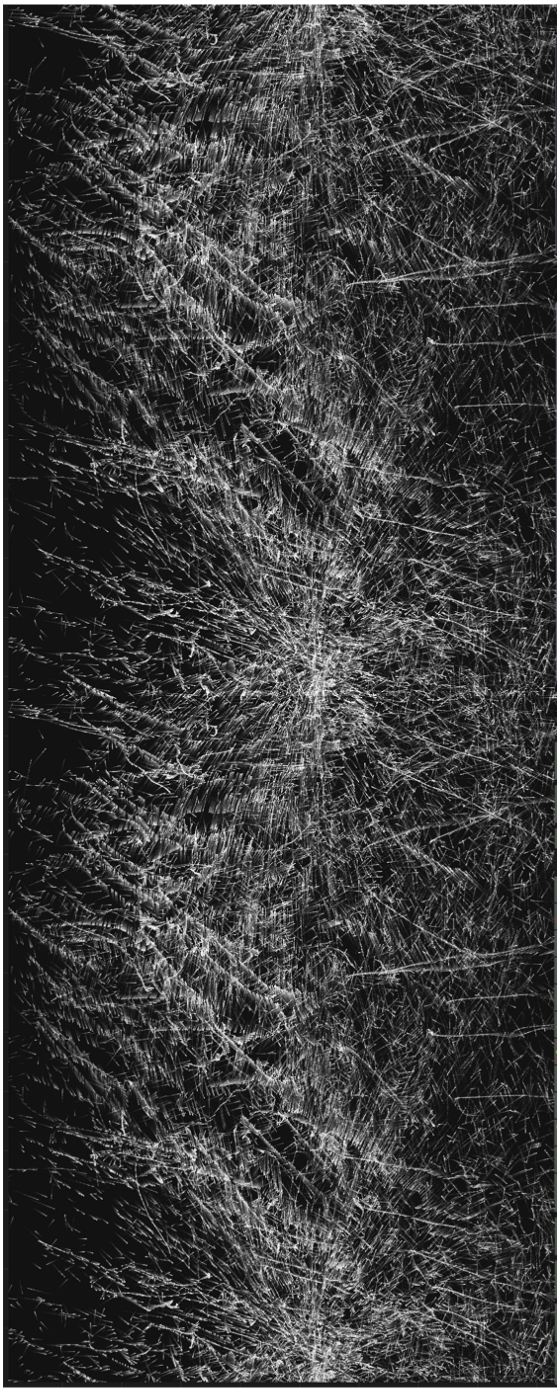


Figure 6.6

Overall, the Point tiles in LUNA[3] were selected to represent a cross-section of rule-based behaviours in fields which have been explored by artists and engineers in the past. These tiles are considered the beginnings of a visual grammar that play with dynamic systems themselves, allowing artists to mix and match different rule-based motions. The total range of behaviours in this language-of-systems is thus greater than any one model. A node which embodies the idea of mixing dynamics is the Combine node. The entire internal code for the Combine node can be found in Figure 5.5 (see chapter five). In one respect, this node is simple as it represents the linear combination (weighted addition) of two points in space. Yet the merging of all points in two moving systems creates a new kind of dynamic itself, a new aesthetic. Figure 6.6 shows the result of combining a Fluid system with a Particle system. Whereas programming in text-based languages changes the rules "underneath" the system, a visual grammar changes the rules "over" the systems. In other languages, such as Houdini, Max/MSP, or Processing, mathematical knowledge would be required to create this combination by writing an expression. This idea of transforming dynamic systems as maleable, whole entities is an interesting way of re-conceptualizing the process of making media art.

New behaviours are revealed to the artist by playing with the system. The *spherify* node takes the points of any dynamic system or object, and maps it to a sphere. Fluid-Spherify results in a points on a sphere whose motion *constrained* to a sphere resembles a fluid. Grid-Spherify maps the points of a grid onto the points of a sphere, creating a

[3]These include several implemented nodes, Particles, Fluids, Spiroid, Combine, Scatter and some not yet implemented ones, Flocking, Brownian, and Surface Points.

kind of crystaline lattice of points. Tree-Spherify takes a tree structure and appears to *press* it against the surface of a sphere. These operations begin to take on the richness and semantic complexity of sculptural processes performed on real materials, but which have been translated into the unique language of computer simulated behaviours. The aspect of LUNA which makes this particularly suited to creative workflows for media artists is the ability to quickly connect tiles without having to remember, program, or 'lookup' the syntax of the language, to interact with these changes in structure.

6.3 Structure and Surface

While the study of simple systems has been greatly enhanced by the ability of artists and scientists to generate images from a set of rules, there are many kinds of systems to be explored. As early experimenters discovered, even a single formulae such as those for fluid equations or fractals can take a lifetime to explore. One aspect that these non-linear systems share is the observation that structure *emerges* from them; there is nothing needed other than the original formulae [Gleick, 1987]. In essence these systems have no explicit parts, but what do we make of objects that do have parts? Trees, molecules, and crystals for example.

What is structure? This may be impossible to answer concretely, but several common ideas emerge. In the natural world, when we observe trees we find that any species is reproduced in a similar but not identical way. We now know that DNA is partly responsible for remembering the form of a particular species. In computer graphics, to generate three dimensional structures, one of the simplest systems is the Lindenmayer system (L-system), a set of typographical rules that transforms on string into another, so as to *grow* trees similar in form to living ones. In computational theory, Alan Turing and John von Neuman explored the idea of an infinite tape, or universal machine, which can encode any algorithm by means of an infinite tape onto which symbols are printed. Each of these ideas share the concept of *memory*, a continuity of experience, a relation or dependency between parts that takes place over time.

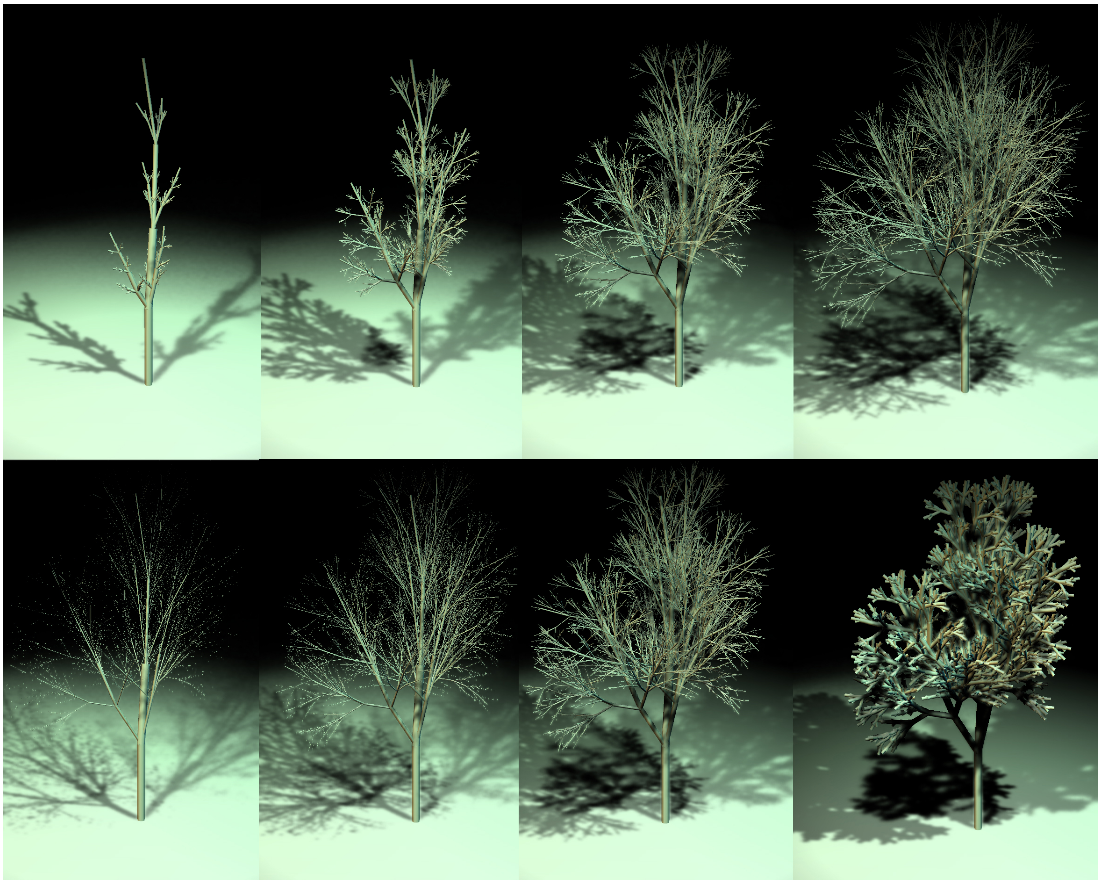


Figure 6.7

What does it mean for an artist to have freedom along the dimension of structure? A simple approach can be derived from the embodiment of a form which is remembered from one instantiation to the next, as a seed produces a unique tree which is also a member of its species. An example of this kind of memory is show in Figure 6.7, modelled and rendered with LUNA. In this example, parameters of the tree are modified while the rules which produce the particular angles between branches are stored so that each change appears to be the same tree in different stages of growth (top row). In the bottom row, this same kind of memory can be applied to other features, which results in a kind of growth not found in nature - the outer branches thicken while maintaining their overall length. The structure retains its shape as various parameters affecting its outcome are modified.

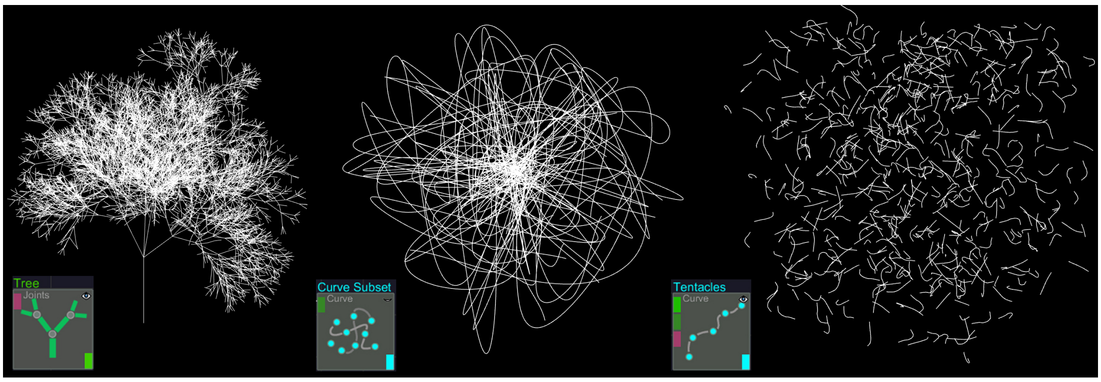


Figure 6.8: Three different structural systems: a) Trees, b) Curve subsets, c) Tentacles

Another kind of freedom in exploring structure extends from selecting different kinds of structures. A tree is an example in which each branch has a particular relationship to its parent branch, continuing recursively back to the trunk. In chemistry, molecules can attach to each other without this hierarchical restriction. In LUNA, Curve Subsets and Tentacles are two other examples of structures chosen for implementation because they both require only a set of points as input, Figure 6.8. Curve Subsets randomly selects, and remembers, a single set of points and connects these with curves. Tentacles chooses a set of points, and then uses a spring system to randomly *reach out* to a different set of points. Many other structure also exist which could be included in LUNA, such as crystals, molecules, articulated bodies, or other arbitrarily generated shapes. It would be interesting to consider whether there are generalizations that could embody the abstract concept of remembered relations between shapes.[4]

What causes an artist to explore a particular structure over another? Why, for example, did I choose one recognizable structure in Figure 6.8, the tree, and two unrecognizable ones to develop in LUNA? The psychology of vision is of importance to the artist since the artist may seek to uphold or upset that vision either consciously or unconsciously. Formalists, such as Wolflinn, considered the psychological development of vision to be central to understand art in different cultures, proposing that there were universal structures in the development of mankind which parallel the development of the individual [Hatt and Klonk, 1992]. This is one way to explain why different forms are of interest in art over time, but does not easily explain how they differ across cultures or periods.

[4]This could potentially allow one to create unpredictable structures with definite forms. While genetic algorithms are another abstraction of memory, the idea here is a way of iteratively producing structures from physical constraints, rather than generating structures from evolving genotypes based on physical performance. The interesting question is how geometric constraints relate to physical structure in an abstract sense.

In the 20th century Saussure explores perception through language, that the memory of a *sign* creates meaning when an image, icon or word (signifier) evokes an idea (signifie). In the example above, the tree-form is an abstract signifier than generates the idea of tree. Interestingly, it is not a word or icon but an abstract simulation of tree that evokes the concept. Roland Barthes provides a social interpretation of this process, whereby the artist may use a particular sign to manipulate or evoke a feeling or idea, a “second-order sign” or myth [Barthes, 1957]. Perhaps the tree is introduced as an example to uphold the notion of strength or knowledge. A problem with this interpretation, however, is that it doesn’t account for the a difference between genuine interest and myth. Is the tree considered in LUNA because society has perpetuated the myth that trees are objects of interest because they are beautiful, or is the tree an object of beauty because it is of interest?

A way of resolving this, from the perspective of tool-making, is to leave these as a choice for the artist and viewer. While the paradox of manipulation versus appreciation may not be resolved by any system, the ability to construct or destruct a sign resides in how easily an image evokes a particular idea. One way in which the reality of an idea is upheld is in the rendering, or appearance, of the object. I view this as a choice in LUNA to be made by the artist.

The rendering in Figure 6.9c creates an illusion of space, and delineates the surface, form and texture in detail using LUNA’s ability to render dynamic scenes in real-time, with shadows, texturing and depth of field (features typically found only in game

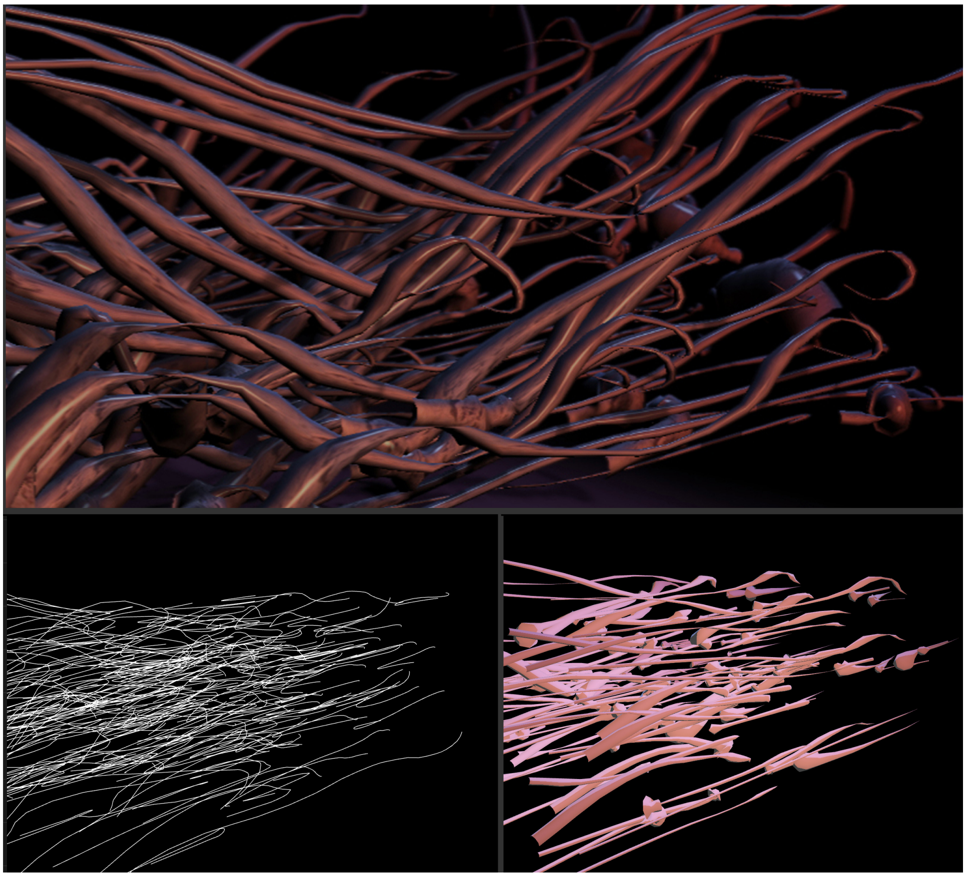


Figure 6.9: Loft surfaces create with different choices in appearance including inner structure, shapes, and illuminated surfaces.

engines). The same forms may be presented in LUNA in other ways, as stylized shapes in Figure 6.9b or simply as curves in 6.9a. The presentation of structure or surface is a choice available at each stage in the construction of the object. To facilitate this, all LUNA nodes have an 'eye' icon that allows the user to enable or disable the intermediate appearances of the object (a similar feature is found in Houdini).

Surface realism was a major area of research while implementing LUNA, since one of the goals was to provide not only the option of realism, but also the ability to control appearance interactively. While game technologies creates a high degree of realism in real-time, the ability to modify or author different looks is typically not part of their interactive workflow and is often performed using offline tools. Therefore, LUNA borrows the idea of material graphs from tools like Maya and combines this with real-time rendering techniques found in gaming. From a graphics perspective, LUNA makes no distinction between interactive appearance editing and high-quality rendering, so that artists do not need to wait for image results to experiment with different looks (in the motion picture industry this is the emerging field of pre-visualization). Artists are also free to author their own appearances by writing Cg shaders which plug into LUNA.[5]

Images do not necessarily require the appearance of a surface to signify an idea, as realism may reside on many levels. Thus, another kind of choice is the ability to modify the context of a structure. The images of Figure 6.10 each uphold a sign in different ways. The left figure is recognizable as a natural (yet simulated) tree due to the ground plane, shadows, and overhead lighting. The right figure is recognized as a biological image, even if we do not know the particular structure it represents (blood vessels and astrocytes) because the structures, colors, and scale relationships between them remind us to microscopic neuronal images. Both objects were rendered using the same Tree object in LUNA, whose context is modified through its relationship to other structures within the graph.

[5] Cg is a language for specify the shaded appearance of an object to the GPU.

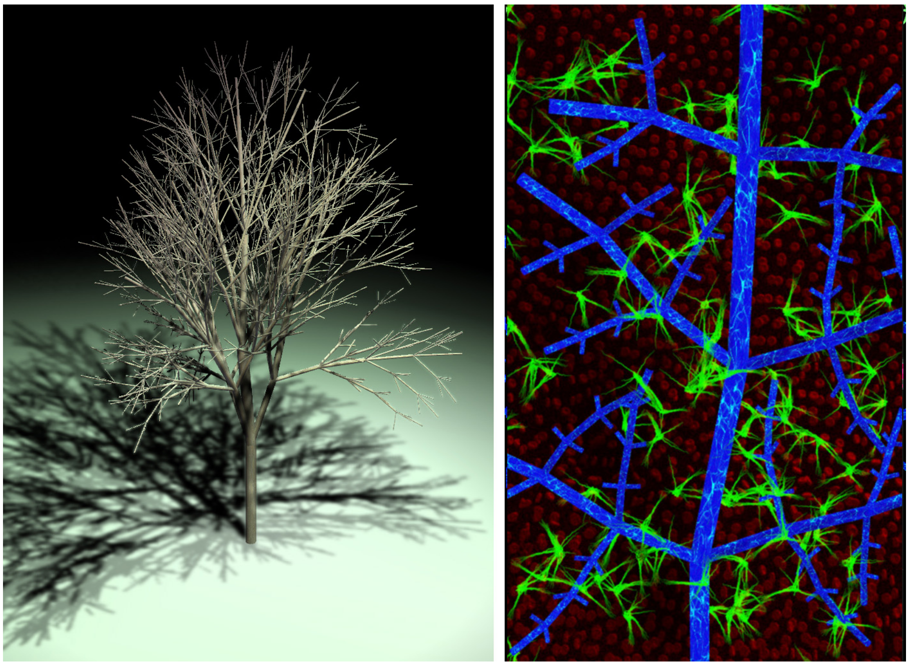


Figure 6.10: Context plays a part in understanding the sign of an object. The same structure was used to create both images.

The idea of image as a form of manipulation led to a reductive and abstractionist phase in art as artists reconsidered the nature of image making. What changes in each work, what remains constant? Structuralists found that the image itself, its context and rules, provide an underlying system for explaining works of art. While views of structuralism differ, Alison Assiter collects a number of these and finds five commonalities:

> "1) The whole forms a system whose elements are interconnected where the structure of the whole determines the position of each element. 2) Structuralists believe every system has a structure: the task of science is to find out what that structure is. 3) Structuralists laws deal not in changes but with co-existence. 4) Structuralists would not deny that dynamics is important in science, but would say that this is complementary to synchronic analysis. 5) Structuralism is a method which examines phenomena as the outward expressions of their inner, invisible structures." [Assiter, 1984]

Aesthetic structuralism is thus a way of analysing art to reveal the sign it upholds, yet from a scientific perspective the idea of structure still contains many challenges. The concept of structure presents a paradox from the perspective of memory. If an image contains remembered signs, then the only way to avoid its status as myth is to consider structures which do not produce recognizable forms. Yet once these forms are exhibited, their structures are committed to memory and they become signs for the future. Thus, the creative dimension of freedom in structure for the artist implies the ability to continually create and destroy the available forms to both break the rules and create new ones.

Figure 6.11: *Tmods*, R.C.Hoetzlein, 2010. Variations in a tree structure are explored by changing the parameters and rules used to generate the new forms.

As low-level languages were initially the only choice available, the approach found in current tools for media artists such as Processing have allowed the artist to create or destroy structures by coding these directly. Consider a tree form needed for a particular project. These structures are interesting to the artist not for the tree itself, but for the various dimensions of change that are possible with them. Examples of some interesting transformations are shown in Figure 6.11. In the current paradigm, to program such a system requires implementing the necessary data structures oneself or acquiring them from a community of artists to be integrated into one's own project. Instead, creative tools for artists would ideally allow for processes of construction, destruction, growth, modification, transformation, and appearance on a variety of existing structures presented in the tool itself. These forms are present not to uphold a sign implied by the structure, but to allow the artist to use them in a larger context, to change or reform them altogether through language. The artist is also still free to build new structures in low-level languages (LUNA's node authorship in C++ for example), but this new choice of transforming structures themselves engages the media artist at a different level than was previously possible.

6.4 Image and Idea

In the Foundation of Computational Visualistics, Jörg Schirra sets out to define a meta-field of study based on the image. His proposal is guided by the observation that different disciplines manipulate images in a variety of ways, and this establishes a basis for understanding how artists, engineers and scientists work with images. This is proposed according to the relation between image and not-image, briefly summarized here from [Schirra, 2005]:

Type of Algorithm	Act / Field(s)
≫image≪ to ≫image≪	Image processing
≫image≪ to ≫not-image≪	Pattern recognition, Computer vision
≫not-image≪ to ≫image≪	Computer graphics, Information visualization

The not-image which Schirra speaks of is everything which is "not defined by the media type image". For example, in computer vision one goal may be to take an image and create a word-label for each object in it. In computer graphics the task of rendering is to take a structure and produce an image. For Shirra, the *concept* must exist in a context as a structure, an essentially connectionist viewpoint. "Objects (as we usually understand the expression) are members of many contexts. What we usually call the identity of objects is basically the question of connecting an object in different contexts." (p.52) [Schirra, 2005]. This helps to explain for Schirra how the tree used in computer graphics, which is a structure embedded in code, is the same "tree" which is a word embedded in the sign-perception of the viewer. Both of these not-images are connectionist ideas, however, while the concept of not-image does not fully represent the status of the other object involved in these processes.

Combining some of the processes collected by Schirra with the different media types developed in this thesis allows us to construct a more complete theory of the digital semantics of the image, shown in Figure 6.12. By digital semantics I mean the different meanings of images and processes as represented by machines. Schirra develops computational visualistics essentially on the functions performed on digital images, which can be found embedded in this figure as the in-going and out-going arrows (processes) acting on the image. Developing the media types further reveals that the sound, written

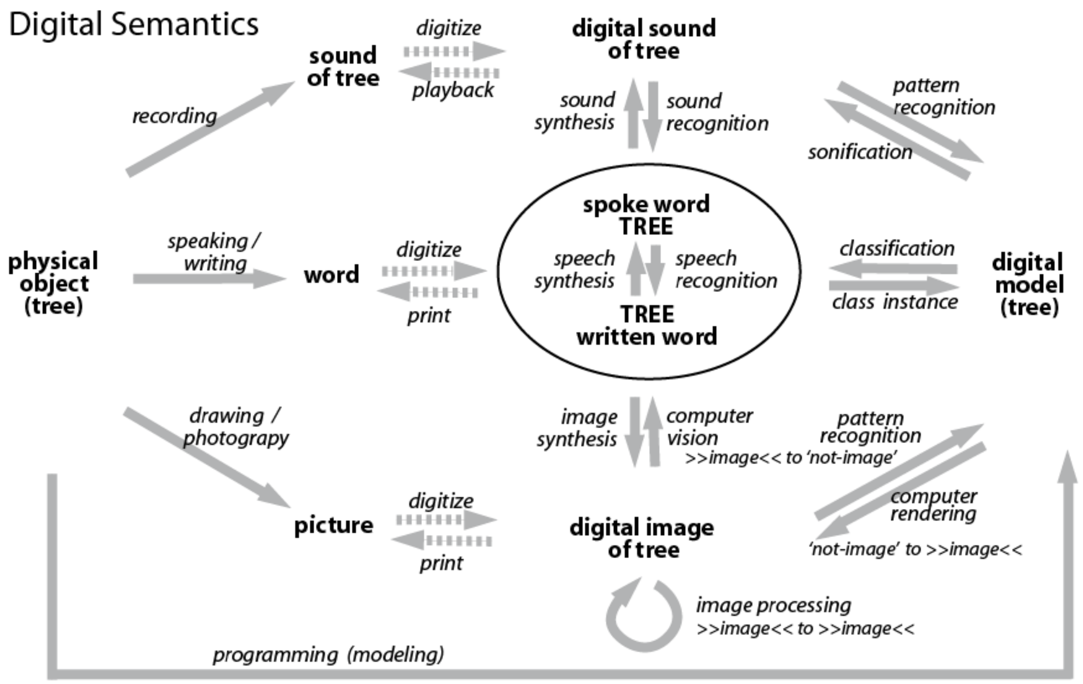


Figure 6.12: Semantics of the digital image and its relation to other forms of representation.

or spoken word, and the digital model are quite distinct from the image, and acted on in different ways by machines.

Overall the diagram is arranged as a relationship between the physical object and the digital model. The digital model is, for example, the structure of a tree as represented by machine as numbers. Interestingly, the digital model has no sensate form, i.e. it cannot be perceived by the senses, without passing through a sense-based media type such as sound or image. We cannot see the data structure of the tree as it exists in the machine without rendering it as an image of a tree. How are digital models constructed? This is one of the acts of programming, to create a mathematical or conceptual model of a real object. However, it is not necessary to have a physical referent to create digital models, which may also be constructed from abstract rules or principles. Thus the physical object is not necessary to make digital models.

The one media type found in this picture, but not yet explored in previous chapters, is the *word*. A word is unique among media types in that it is a symbol, in the sense used by Pierce to distinguish icon, index, and symbol; it is an abstract representation of a thing [Peirce, 1931] (2.228). Put another way, the word for "tree" could refer to *any* tree, and does not embody a particular tree whereas all the other types of media do. So, whereas a digital model can provide a particular shape or form without a word, a word can provide an idea without the particulars. Neither of these yet involve the digital image, so we are speak here of language. In fact, in programming languages, the translation of a word into a replicated model by machine is called *instancing*[6], and the reverse process of deducing a word from the pattern of a model is *classification*, both of which can be seen in the figure.

Two processes involving the digital image, not previously studied, have to do with the relation between words and images, and are thus areas which media artists may be interested in exploring. These are image synthesis and computer vision. Image synthesis is the process of creating an image from a semantic label (word), while computer vision is the process of determining a word given an image. The final dimension of freedom for media artists considered in this chapter is the relationship between images and words. It should be emphasized that this does not imply a particular value structure toward

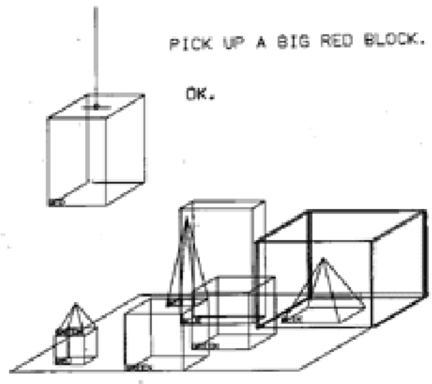
[6]Instancing is to create an instance of a class. The computer must be told what the model is in a particular way, along with the word that defines it. Any number of *different* instances can then be requested on demand.

specific words or their referents. In Saussure's terms, there is no *signifié* anywhere in the figure above as every media type is a referent, including written words, since a word only becomes a complete sign in relation to human perception and memory (or context) [Saussure, 1965]. Words evoke meanings, but to the machine they are another type of data. That meaning should be a matter of choice for the artist, where possible processes are offered by the tool.

6.4.1 Image Synthesis

In 1968, Terry Winograd developed a system called SHRDLU, a system in which various shapes of different colors and sizes (blocks, spheres, cones) could be arranged in a simulated world [Winograd, 1971]. The user could then instruct the machine, using English sentences, to rearrange the blocks based on language. Figure 6.13 gives an example of a dialogue with SHRDLU.

The unique aspect of SHRDLU is the connection made between a visual, three-dimensional world and the semantics of language. SHRDLU contains a toy model of a world which the user creates and modifies entirely through written dialogue. This world is interesting from a media arts perspective since the representation is a visual one, and is thus a form of image synthesis. What is the relationship between computer rendering and image synthesis? Rendering is the process of forming an image from a digital model, which may not require written words (see earlier map). In the examples of *Spira* in the preceeding section, no words were needed to create these images, only a model. While



Person: Pick up a big red block.
Computer: OK.
Person: Grasp the pyramid.
Computer: I don't understand which pyramid you mean.
Person (changing their mind): Find a block which is taller than the one you are holding and put it into the box.
Computer: By "it", I assume you mean the block which is taller than the one I am holding.
Computer: OK.
Person: What does the box contain?
Computer: The blue pyramid and the blue block.
Person: What is the pyramid supported by?
Computer: The box.
Person: How many blocks are not in the box?
Computer: Four of them.
Person: Is at least one of them narrower than the one which I told you to pick up?
Computer: Yes, the red cube.

Figure 6.13: SHRDLU, by Terry Winograd (1968), allows a user to move around blocks in a virtual world using natural language.

digital models may reside on many different levels image synthesis considers models that include the use of written language, as SHRDLU does.

In certain areas of visual arts such semantic systems already exist. Cohen's unique AARON software achieves automatic drawing of human figures and plants using a set of semantic rules [Cohen, 1979], Figure 6.14. AARON is instructed on the *semantic*, word-meaning relationships between parts of the body to automatically generate compositions. In organic art, systems like Xfrog are capable of generating plants with roots, stems, leaves, and branches based on the labels of words assigned to different parts. Although any model is ultimately a simplification of reality, it is interesting to consider how far semantic systems could go in describing aesthetic or imaginative objects. Is it possible to describe and animate complete imagined world by semantic means? I consider this an open question, and one which is not presently answered by LUNA. The

Figure 6.14: Aaron's Garden, 1989. Pen and ink drawing by AARON software created by Harold Cohen.

language of LUNA was developed to move toward this goal, however, by observing that such a system would need to create *structural* and *functional* relations between objects. Currently these are embodied in the line connections created within a visual graph.

The relationships between the parts of different objects in Aaron's Garden are physical attachments, A is connected to B. Parts have physical relations to other parts. However, relationships between objects are also conceptual and symbolic. The ways in which these word-relations might be potentially interpreted by machines is as complex and varied as the behaviours and structures explored in the preceding sections, yet aside from AARON there are few other examples of semantic drawing in media art.

Figure 6.15: *Dream Caused by the Flight of a Bee Around a Pomegranate a Second Before Awakening*, Salvador Dali, 1944.

Consider the image of Figure 6.15. This image, *Dream Caused by the Flight of a Bee Around a Pomegranate a Second Before Awakening* by Salvador Dali (1944), presents a more complex semantic. We might describe this image formally as "A nude figure floats over a stone slab suspended above a blue plane. Over her body, poised at the neck, a gun with a bayonet is released by a tiger jumping from the mouth of a lion, which jumps from the mouth of a goldfish, which jumps out of a pomegranate. In the distance, an elephant with extremely long bony legs carries an obelisk." Certainly no system could ever be expected to reproduce this image exactly without further details relating to scale, placement and shading of the objects, it is interesting to consider whether this might be possible at all. Such a system would need to be familiar with the objects in the image, as well as the parts of fruits, animals, and humans.

This example by Dali points out several paths, as image synthesis may take many forms. The form explored by AARON is an verb relationship between parts - 'An arm is next to a body. A head is above it.' The objects in Dali's painting have more to do with action relationships between objects suspended at a moment in time. One approach might be to *build* a scene from a large collection of three dimensional models stored in memory, while another could be to allow dynamic models to actively engage in word actions described by the user which are then "recorded" by rendering a moment in time. This example by Dali was chosen due to the wide range of meanings present, but also to highlight the complexity of these task with real world objects. However, the meaning-system of Dali's surreal representation is not necessary to explore this dimension of creativity. The words used could be the sequences of DNA strands (a typographic system), or perhaps poems, producing dynamic images based on abstract models as Michael Rees does in his work *Putti*.

Figure 6.16: *Social Evolution*, R.C. Hoetzlein, 2008

The simplest way to explore image synthesis is through memory. A word evokes an idea, which in its simplest form may be represented in the machine as a database of images from which a choice is made. *Social Evolution* is a project by the author which pre-dates LUNA, but which could be more easily represented in LUNA using constructs for image synthesis. Social Evolution consists of characters engaged in verbal acts such as walking, running, sleeping, harvesting, killing and eating, and was developed by hand-sketching a series of characters in various poses (Figure 6.16). The system for Social Evolution required programming of image selection, behaviour, and image synthesis. This example has not yet been converted to LUNA, but could be accomplished using the Image Scatter object, taking a set of locations determined by behaviour and placing these at locations in a scene.

At one point, I considered developing digital models to generate the image database for new experiments in image synthesis, but made an interesting discovery with hand drawn structuralist figures. These images, titled *Puzzles*, are shown in Figure 6.17. A digital model is a structure which by definition involves a set of known rules used to produce a form, since it must be interpreted by machine. What are the rules used in figure 6.17? Two obvious rules are the concept of the nearly closed square as a starting point, and the use of an uninterrupted line. A third might be the idea of deviation but this can be deduced from the first two. However, these three rules alone are insufficient

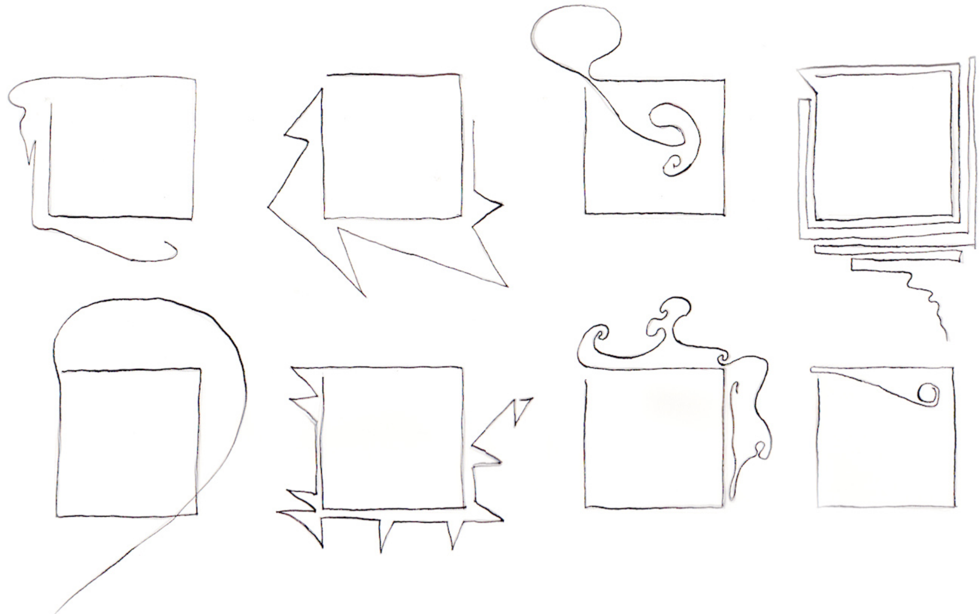


Figure 6.17: *Puzzles*, R.C. Hoetzlein, 2010. Ink on paper.

to digitally reproduce the shapes create here. One might state that there is an abstract rule which is, "Create a series of curves which try to break a pattern.", which could describe the psychological or conceptual process involved, but this also is insufficient to reproduce these images since even knowing this fact does not allow one to explain why these *particular* shapes were created. While these figures may have been created by some internal rule within the artist, that process is inaccessible to us. This aspect of the hand drawn image, to have content without known rules, is a unique distinction from the digital model, which *requires* rules for machines to interpret them. The integrated use of images in LUNA is essential in allowing artists to mix digital models with non-formal images.

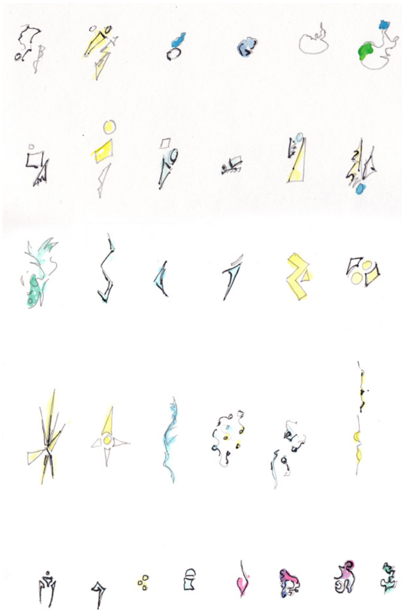


Figure 6.18: a) *Automatic Fragments*, R.C. Hoetzlein, 2010. Ink and water color on paper. b) *Automatic Drawing*, André Masson, 1924. Ink on paper.

Figure 6.18a show a series of sketched fragments created using a similar process, working within a structure while being intentionally difficult to formalize. Whereas the *Automatic Drawing* of Andre Masson shift between a "sub-conscious process" and brief fragments of a recognizable figure, Figure 6.18b, the drawings created here shift between rule-based fragments and rule-less fragments. Thus, although these hand drawn fragments cannot be understood in terms of any formalized rule system they also remain abstractions without reference to a particular sign.

The images in figure 6.19 are a collaboration between these hand drawn fragments and computer generated composition. The use of drawing intentionally produces a form

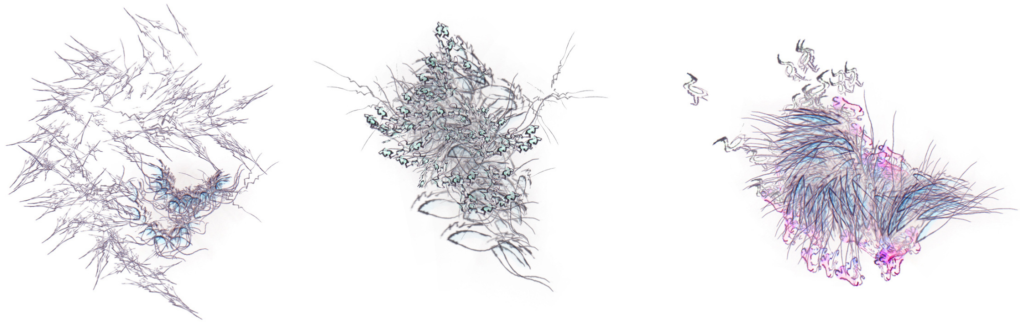


Figure 6.19: *Fragment Collage*, R.C. Hoetzlein, 2010. Fragments of hand drawn images are composited by the computer using generative algorithms.

with no known rules through a process similar to automatic drawing. The computer participates in the process by determining the placement and composition of the drawn fragments using a generative rule system which is known, but which also carries no sign-meaning as a recognizable idea. The result is a man-machine collaboration in which the image contains abstract formalized rules, yet carries no descriptive connotation, and which cannot be recreated in its entirety by any set of known rules.

Figure 6.20: *Sequence*, R.C. Hoetzlein, 2010. A continuous curve with a sequence of structural deviations presents a particularly difficult challenge for computer synthesis.

A final series of drawings further demonstrates the idea. *Sequence*, figure 6.20 is a number of continuous curves with structural deviations along its length, such that the whole line would be very difficult to formalize by machine. These experiments show that there is potentially a continuum between object or word-based image synthesis as found in Social Evolution and purely generative synthesis found in *Fragment Collage*. The contribution of image synthesis, as a process, is that it may or may not involve an idea (word form) but in both cases, by relying on external hand drawn shapes, the image can be one in which rules are optional. To render a digital model requires formal rules for instructing the machine how to transform the model into an image, while synthesizing an image only requires memory.

This final image, figure 6.21 shows more rendered version of a Fragment Collage along with the LUNA graph used create it.

6.4.2 Computer Vision

As a general technique, computer vision has found a presence in media arts since in the 1970s as exemplified in Myron Krueger's *Videoplace*, an environment for human interaction with virtual spaces [Krueger, 1991]. More recent examples, such as Golan Levin's *Footfalls* (2006) encourages participants to play with digital circles released by the sound of stomping participants while visual detection enables them to hold and collect these virtual balls. Both works essentially treat the participant as a body-form whose silhouette is recognized as an interacting shape. In a later project, Opto-isolator (2006), Levin collaborates with engineer Greg Baltus to develop a mechanical eye which

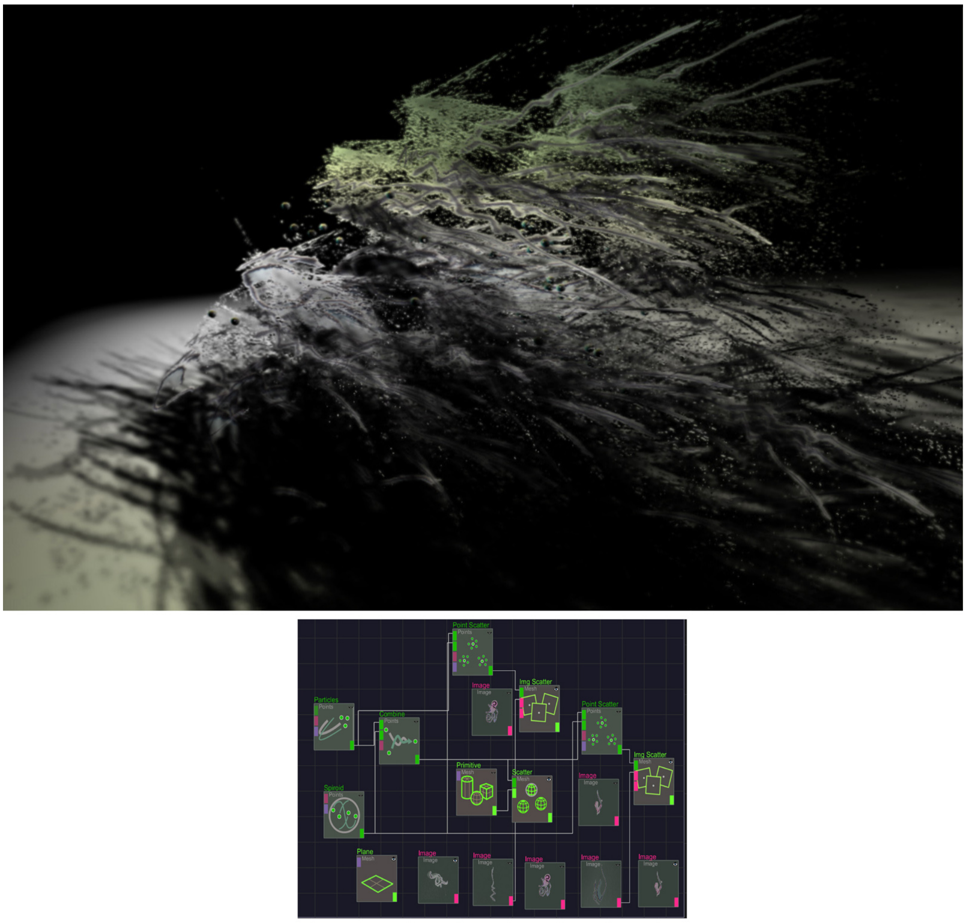


Figure 6.21: *Dark Fragments*, R.C. Hoetzlein, 2010.

follows the visitor own gaze, blinks, and looks away. In general, these techniques use computer vision to transmit the gestural interaction or facial features of the participant into the machine. This method was also used in *Presence*, a collaboration between myself and Dennis Adderton using LUNA to present a 360 degree panoramic photograph which reorients toward the view as one walks around it. A recent article by Levin [Levin, 2006], demonstrates that computer vision is still a developing field in the arts as techniques for object recognition of the image, i.e. semantic labeling, have not yet made their way to media artists.

In other communities, however, engineers that specialize in computer vision have been making rapid progress. Bay et al. develop a cell phone application that allows art museum participants to photograph a work of art and receive an instant identification of the object, with an accuracy of 82% [Bay et al., 2006]. Takacs et al., working with Nokia, created an outdoor application that identifies part of an image in photographs taken using a cell phone [Takacs et al., 2008]. These examples represent the current state of the art in computer object recognition, transforming a digital image into a set of word labels.

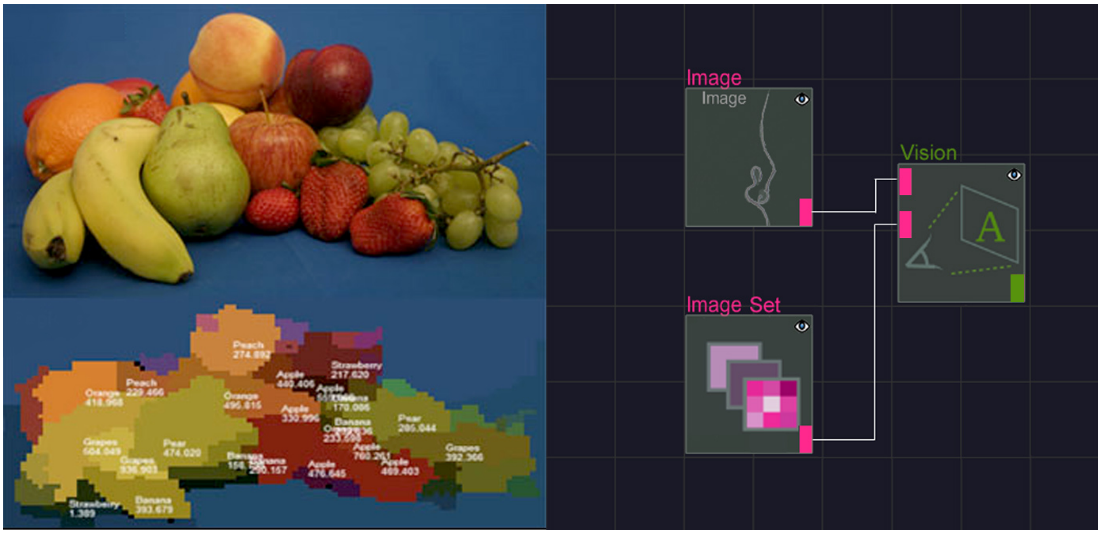


Figure 6.22: Computer vision in LUNA with two inputs, 1) an image set representing a memory of objects, fruits from various angles and 2) a target image of a still life to be detected (top left), produces a set of labelled points (bottom left) of detected objects.

A similar experiment may be performed in LUNA on still life photographs by developing a process to detect regions of color in images[7], figure 6.22. In a reversal of image synthesis, which uses image memory to generate new compositions, this method takes an image and detects regions in relation to that image memory. In this case, the memory stores a collection of fruits at various angles and the machine takes the input image and generates a set of word labels and locations. This introduces a new media type in LUNA, a Text object, which derives from a point set that includes labels. This Text object may also be used in the future for information visualization, as labels are assigned to geometric locations based on information contained in a database.

The generation of images from digital models is a well developed area of computer graphics as the need to create visual representations of computer models - whether they are abstract, realistic, rule-based or informational - is an important technique in several fields. Relatively speaking the relation between *words* and images is still largely unexplored by media artists, since methods for image synthesis and computer vision are potentially more complex. To facilitate the exploration and expansion of media arts into other media, other processes, and other ideas, these facets of the digital image are introduced in LUNA as building blocks to be interacted with, while their future growth is in the hands of the artistic community.

[7]Based on work done in a graduate class with Prof. Matthew Turk at UC Santa Barbara.

6.4.3 Conclusions

The development of this thesis has proceeded along several lines of thought, or dimensions, related to form, data and technique in media arts. The creative features of digital tools to provide low threshold, high ceiling, and wide walls are employed as evaluative criteria to varying degrees in LUNA through the design of the language, its interface, interaction, and the number and types of media both potentially and currently available in the system. LUNA allows several basic dimensions for creative workflow. These include 1) the ability to author new models in text-based languages and also through the interactive visual interface, 2) the ability to work with different media types including video, images, and geometric shapes, surfaces, and materials, and 3) the ability to adjust performance and rendering quality to meet the particular needs of live performance.

In the area of content, this work has explored 4) motion and dynamics, 5) structure, and 6) image and words. The construction of these arguments is based on the concept of creative *dimensions* in media arts. In the process of exploring content, however, it becomes apparent that there are several facets to each particular mode of working. Thus these dimensions should not be considered as Cartesian generalization of the space of work explored by media artists. Certainly the examples considered here may be thought of as points within a particular dimensions or context, but beyond this each dimension should not imply a linear map for expression. Rather, these dimensions should be understood to refer more loosely to sets of opposing and complimentary practices which take place within media arts. The actual choices themselves, however, exist along a complex number of features related to each type of media based on specific decisions of the artist. The content of LUNA explores a particular space of media arts in the area of geometry, form and media, one which is possibly wider overall by design than other tools for artists, but still a series of choices based on the authors interest in sculptural, interactive, and generative forms in relation to word-concepts.

How the artistic community conceptualizes and develops creative tools plays a major role in defining the kinds of art that will be created in the future. Computer vision and image synthesis, for example, are novel approaches to considering images and ideas, yet are largely unexplored due to the high threshold for entry into these methods. Yet this limitation focuses and drives artistic work into more easily accessible areas such as modelling and rendering and thus forces decisions in content. To overcome this, it is necessary to redefine creative tools not in terms of their current abilities and features, but in terms of the space of possibilities which can be expanded as the field evolves. The contribution of this work has been to propose and show that several of these dimensions which have become separated over time into tools for distinct communities, may be brought into existence together through a consideration of their relationships and constraints. The final purpose of which is to enable and encourage creative work with digital media in different, potentially better ways, without having to repeat work while coming closer to expressing what one hopes to as an artist.

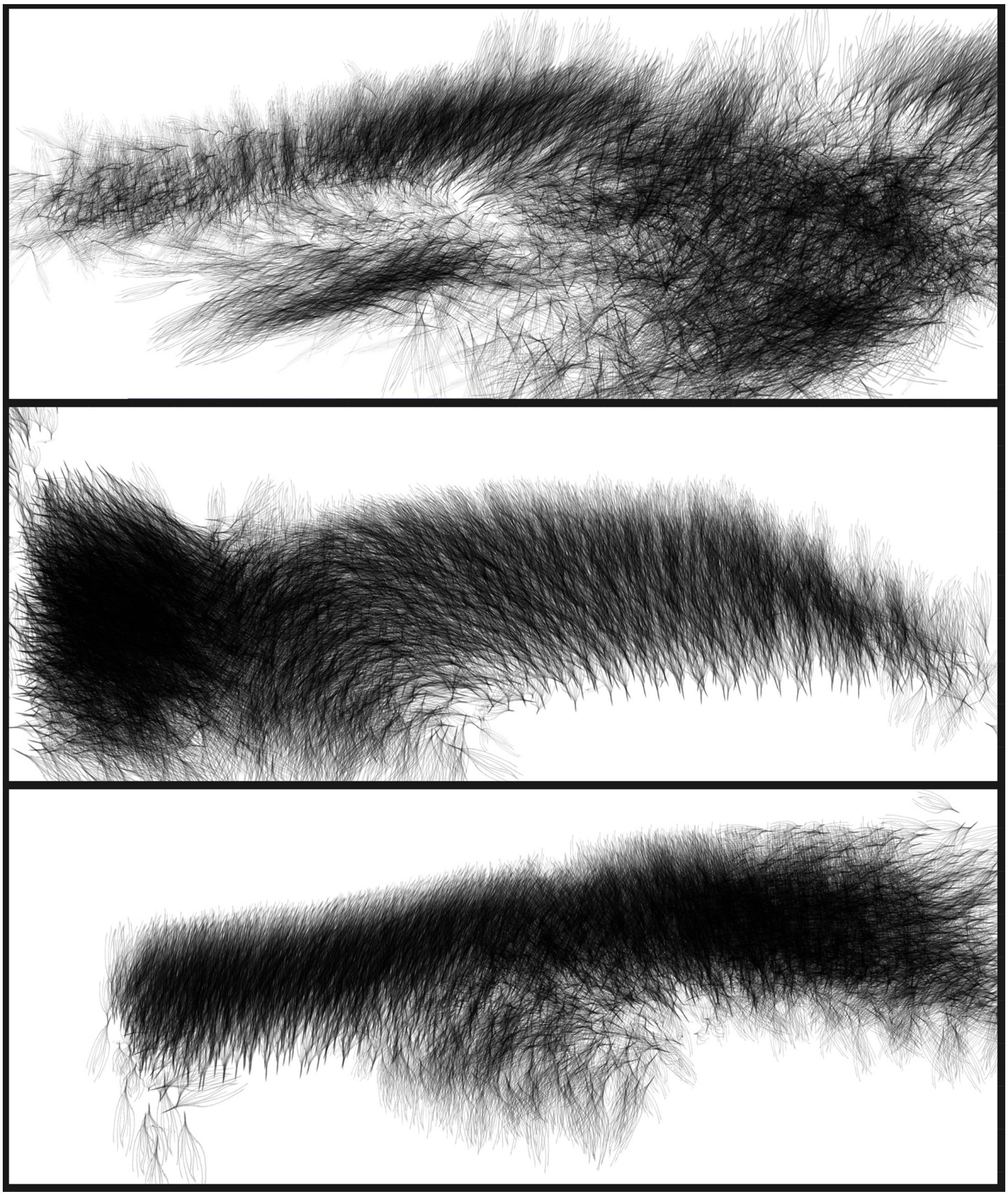


Figure 6.23: *Soft Sketches*, R.C. Hoetzlein, 2010. Ink on paper with computer generated composition.

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