

Research Paper

*Math, Science, and Technology in Contemporary Sculpture*

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Without the mathematic, scientific, and technological advances of the 20th century, the contemporary sculptures of Theo Jansen, Robert Lang and Julian Voss-Andreae would not be possible. Each of these artists uses math, science and technology in their artwork to varying degrees. Theo Jansen began his sculptural work with a base of computer-generated numbers and has evolved his series of sculptures from that base. Robert Lang uses computer technology to apply mathematics to the creation of original origami figures. Julian Voss-Andreae is concerned with the visualization of complex scientific theories and molecules that make up the world in which we live. Each of these three contemporary artists use breakthroughs in math, science and computer technology to create works of art that would not have been possible one hundred years ago.

Theo Jansen is a kinetic sculpture artist born and based in The Hague, Netherlands. Jansen, once a painter with a physics background, now spends his time creating new forms of life. Jansen calls these sculptures *Strandbeest* or beach creatures.<sup>1</sup> His aim is to create a herd of beach-dwelling creatures that can save the people of the Netherlands from the rising tide of the ocean by building the sand dunes higher over time.<sup>2</sup>

*Animaris Currens Vulgaris* (Figure 1) is a beach animal created by Theo Jansen in 1993.<sup>3</sup> Perhaps the two most readily notable aspects of *Animaris Currens Vulgaris* are its unique composition and movement. *Vulgaris*, as the majority of the *Strandbeest* series are, is composed nearly exclusively of two materials: yellow plastic electrical tubing and nylon cable ties. Jansen considers the electrical tubing to be akin to the proteins that constitute the human body.<sup>4</sup> Proteins are commonplace in living organisms and are not exclusive to humans, yet they are essential. Proteins compose the genetic code, which make a person or organism unique. The yellow plastic tubing is especially commonplace in the Netherlands where it is the legal standard for electrical wiring in building construction. However, Jansen is able to take this basic tubing and create many different animals. Each animal is a combination of varying lengths of plastic tubing, arranged in an angular, bridge-like, architectural fashion, held together by cable ties.

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<sup>1</sup> Theo Jansen. "Strandbeest.com." Strandbeest.com. <http://www.strandbeest.com/index.html> (accessed January 24, 2010).

<sup>2</sup> Theo Jansen. *Theo Jansen: The Great Pretender*. Netherlands: 010 Uitgeverij, 240

<sup>3</sup> Ibid., 240

<sup>4</sup> Codin Pangell. "Project2501: Kinetic Sculptures." The future of everything. <http://spacecollective.org/Project2501/1478/Kinetic-Sculptures> (accessed March 8, 2010).

*Animaris Currens Vulgaris* is especially significant in the development of the *Strandbeest* series because it is the first creature Jansen created that can stand on its own and walk. *Vulgaris*' skeletal form measures 1.4 meters wide, 2.1 meters high, and 2 meters deep.<sup>5</sup> Its body arcs toward the center and makes up approximately the top third of the sculpture. The beach animal rests on a set of twelve legs, spread evenly horizontally, always at a different point in the walking cycle. The legs are the mesmerizing focal point of the piece, complex yet rhythmic in movement. Each leg of a *Strandbeest* creature is created from electrical tubes of eleven lengths. Jansen refers to the lengths, including the length of the crankshaft, as the "Twelve Holy Numbers".<sup>6</sup> Each length is extremely important to the movement of the sculpture. Before the numbers were known, no creature of Jansen's creation was able to walk.

The locomotion of the *Strandbeest* leg resembles that of a real animal to a certain degree. Jansen's sculptures walk by picking up one leg just as another sets down, and yet another is in motion to take the place of the next. As the crankshaft turns, the feet of the sculpture move in a deflated oval shape, touching the ground for approximately one third of their movement. Jansen realized early on that the animals needed to walk on the beach because a wheel is much too difficult to move through sand.<sup>7</sup> Instead of using trial and error to figure out the combination of lengths that would create the perfect gait, Jansen created a program on the computer. Using genetic algorithms, Jansen was able to create an application that evolved the movement of the leg over time by testing different length combinations digitally. The program started with a random set of lengths, and after a short number of months Jansen had his numbers. When asked how he came up with the numbers, Jansen freely admits the computer did most of the work.<sup>8</sup> But without the computer Jansen would have been left with a mind-boggling eleven trillion possibilities.<sup>9</sup>

*Animaris Currens Vulgaris* was not Jansen's first foray in computer-aided evolution. Inspired by *The Blind*

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<sup>5</sup> Jansen, *Theo Jansen: The Great Pretender*, 236

<sup>6</sup> *Ibid.*, 57

<sup>7</sup> TED. "Theo Jansen creates new creatures | Video on TED.com." TED: Ideas worth spreading. [http://www.ted.com/talks/theo\\_jansen\\_creates\\_new\\_creatures.html](http://www.ted.com/talks/theo_jansen_creates_new_creatures.html) (accessed January 24, 2010).

<sup>8</sup> Jansen, *Theo Jansen: The Great Pretender*, 57

<sup>9</sup> *Ibid.*, 56

*Watchmaker*, by Richard Dawkins, Jansen set out in the spring of 1990 to witness evolution.<sup>10</sup> Jansen wrote a program to create *Animaris Lineamentum* (Figure 2). The *Lineamentum* animal was essentially the first work in the *Strandbeest* series and was the starting point for Jansen's explorations in genetic algorithms on the computer. Though *Lineamentum* was only a digital program, Jansen was able to envision evolution in a tangible way. With each generation the computer created a set of black lines on a white background, each line with four segments. To begin, each segment had a random curve. Each line had a tail and head section and on each head a stinger. As the animals moved around the screen, they stung each other. Death occurred with just one sting, eliminating a certain population every round. At the end of each generation the most effective *Lineamentum* were able to reproduce, then the program was run all over again. Without this initial exploration in *Lineamentum*, Jansen would never have come up with the idea to create a program that would discover the Twelve Holy Numbers. And without the aid of the computer, the use of genetic algorithms, and the Twelve Holy Numbers, Jansen's *Strandbeest* would not be the unique sculptures they are today.

Robert Lang is an American-born artist who uses mathematics, computers, and laser technology to advance the complexity of his original origami designs. Since the age of six Lang has been involved in the world of origami, but up until ten years ago he did not consider the art to be a full-time profession. Instead, Lang applied himself to the study and application of physics, a profession from which he created more than forty patents and published more than eighty papers.<sup>11</sup> Lang's involvement in physics gives him a solid foundation in mathematics and technology from which to grow his artistic abilities.

Origami as an art has seen a boom in the last fifty years. Before the twentieth century only around one hundred original origami designs were published, but in the last fifty years that number has grown to more than 36,000.<sup>12</sup> One catalyst was the publishing of a diagramming system in the 1950s by Akira Yoshizawa.<sup>13</sup> Another catalyst is the advances made in mathematics in the last century and the application of those advances to origami in

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<sup>10</sup> Ibid., 13

<sup>11</sup> Susan Orlean. "The Origami Lab." *The New Yorker* 83, no. 1 (February 2007): 112, 114, 116, 118-20. OmniFile Full Text Mega, WilsonWeb (accessed February 5, 2010).

<sup>12</sup> TED. "Robert Lang folds way-new origami | Video on TED.com." TED: Ideas worth spreading. [http://www.ted.com/talks/robert\\_lang\\_folds\\_way\\_new\\_origami.html](http://www.ted.com/talks/robert_lang_folds_way_new_origami.html) (accessed January 24, 2010).

<sup>13</sup> Beth Jensen. "Into The Fold." *Smithsonian* 38, no. 3 (June 2007): 74-7. OmniFile Full Text Mega, WilsonWeb (accessed February 5, 2010).

the last two decades. In the early 1990s Lang and another origami master, Toshiyuki Meguro, both independently recognized that origami was fundamentally a mathematics problem.<sup>14</sup> Mathematics is the key to complex origami design because each flap or appendage of an origami figure must originate from a circular section of paper. Thus, the more circles an artist can fit on a page, the more intricate the figure can be. Lang refers to this problem as a "circle-packing" problem and references previous mathematicians for help in solving it.<sup>15</sup>

Lang's response to the revelation of origami as a mathematics problem was to create a program named *TreeMaker* (Figure 3) in the early nineties that was designed to formulate a "non-trivial origami figure based on a description of the number, lengths, and connectedness of the flaps."<sup>16</sup> Within a number of months Lang wrote the first version and by 1998 he had released *TreeMaker 4.0*, which could solve origami problems that Lang could not solve with traditional pen and paper. *TreeMaker* is now capable of taking a line drawing input and computing the folds that will be needed to create nearly any figure.

*ReferenceFinder* (Figure 4) is another program Lang wrote in the 1990s, meant to accompany *TreeMaker*.<sup>17</sup> Where *TreeMaker* works to solve the problem of the placement of flaps and folds on a page, *ReferenceFinder* works with the problem of folding an object once the crease pattern is mapped out. Before *ReferenceFinder* origami artists were left with a trial-and-error approach to folding figures. Even if they could map out the creases, they then had to make the folds in the correct order that would result in the intended figure. *ReferenceFinder* uses seven folding operations, known as the Huzita-Hatori Axioms, to calculate the best possible folding sequence for a given figure. The Huzita-Hatori Axioms come from the discoveries of the first six axioms in 1989 by Humiaki Huzita, and the last one by Koshiro Hatori in 2001. The axioms are essentially a set of mathematic rules that define how paper may be folded. Because the axioms are expressible in equation form, Lang recognized the ability to create a computer program based on those formulas. By 2003, and the third version of *ReferenceFinder*, all seven axioms had been integrated and could generate the folding sequence for virtually any set of crease patterns.

With *TreeMaker* and *ReferenceFinder* in hand, and the use of a commercial precision laser cutter to score

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<sup>14</sup> Ibid.

<sup>15</sup> TED. "Robert Lang folds way-new origami | Video on TED.com."

<sup>16</sup> Robert J. Lang. "Robert J. Lang Origami." <http://www.langorigami.com/science/treemaker/treemaker5.php4> (accessed January 24, 2010).

<sup>17</sup> "Apple - Science - Profiles - Robert J. Lang, pg. 1." Apple. <http://www.apple.com/science/profiles/origami/> (accessed January 24, 2010).

paper, Lang is able to create works of art that would not be otherwise possible. One such work is *Rattlesnake, opus 539* (Figure 5), a private commission in 2008 that features a paper snake coiled in a defensive posture, tail up as if to shake its rattle as a warning before it strikes. The tail itself forms ten beads and the body features approximately one thousand scales. The head contains nostril indentations and an open mouth. The snake is folded from one uncut rectangle of shiny brown Thai unryu paper and at completion is approximately 8" in size.<sup>18</sup> The incredible precision of the folds and the intricacy of the scales and rattle make the piece incredible and nearly unbelievable under the standard constraints of origami. The viewer is left wondering how such a figure could be folded from one single, uncut sheet of paper. The details of *Rattlesnake, opus 539* serve as evidence of Lang's ability to harness math and technology and apply it to his art.

Lang's complex origami is often referred to as computational origami because of his use of mathematics and the computer. Without the mathematic discoveries of the Huzita-Hatori Axioms, the development of the computer as a tool for complex calculations, and without the laser cutter to aid in folds, Lang's artwork would not be possible. For his ability to merge math, technology and ancient art, Jan Polish of Origami USA calls Lang the "renaissance man of origami."<sup>19</sup>

Julian Voss-Andreae is an artist, turned scientist, turned artist once again. He grew up painting, and began his artistic career as a realist painter. When painting ceased to be interesting to Voss-Andreae in 1993, the artist turned to science and worked for the next seven years to eventually complete Physikdiplom in Europe - essentially a Master's of Science in Physics. While attending university Voss-Andreae participated in research regarding quantum physics. That research inspired the scientist to return to his artistic roots, move to Portland, Oregon and complete a BFA in Sculpture at Pacific Northwest College of Art. Julian Voss-Andreae now spends his energy interpreting, visualizing, and sculpting science phenomena.

Voss-Andreae finds inspiration in protein molecules and other underlying structures essential for human life. His sculptures are based on tested scientific knowledge, but Voss-Andreae uses a certain artistic license. On this subject, Voss-Andreae has much to say:

There is always a danger of taking any image or model too literally. Using images in science or

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<sup>18</sup> Robert J. Lang. "Robert J. Lang Origami." [http://www.langorigami.com/art/gallery/gallery.php4?name=rattlesnake\\_1](http://www.langorigami.com/art/gallery/gallery.php4?name=rattlesnake_1) (accessed January 24, 2010).

<sup>19</sup> Jansen.

philosophy to illustrate states of affair is generally a two-edged sword because it is essential that the audience knows the limits of a picture and uses it with discrimination and intelligence. With that caution, I believe that art, having shed the requirement to visually represent reality accurately, is uniquely capable of instilling an intuition for the deeper aspects of reality that are hidden to the naked eye.<sup>20</sup>

For Voss-Andreae it is important to communicate the spirit of the science, with an eye for form. *Angel of the West* (Figure 6) is one of Voss-Andreae's most visually stunning sculptures and represents his unique approach to science and art.

In 2005 Voss-Andreae was commissioned to create a sculpture for the entrance of The Scripps Research Institute in Florida based on the molecular structure of the human antibody. *Angel of the West* is a 1500-pound sculpture with a twelve-foot vertical diameter and a four-foot depth.<sup>21</sup> The piece is made up of 1336 pieces of rectangular stainless steel tubing, assembled into ninety "beta strands."<sup>22</sup> The beta strands were then assembled to mirror the layout of Da Vinci's *The Vitruvian Man* with eighteen stainless steel rods radiating from and supporting the body and wings of Voss-Andreae's antibody angel.<sup>23</sup>

Many of the artist's sculptures are created from mitre-cut metal pieces welded together, but *Angel of the West* required more technology than simple welding equipment. To execute the piece, Voss-Andreae employed computer technology in the form of a custom program he wrote to envision how the beta strands might fit together. Once the artist found the configuration he was looking for, he wrote another program to calculate the various mitre cuts that he would need to be made to each piece of metal, and then executed those cuts on a laser-cutting machine. All together, the programming took Voss-Andreae six months to write - but without the aid of the computer, the sculpture would be an impossibility.<sup>24</sup> Once the programs were written and the pieces cut to size, it took Voss-

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<sup>20</sup> Julian Voss-Andreae. "Quantum Sculpture: Art Inspired by the Deeper Nature of Reality." Julian Voss-Andreae: Science Sculpture. [www.julianvossandreae.com/Work/QuantumSculpture/QuantumSculptures.pdf](http://www.julianvossandreae.com/Work/QuantumSculpture/QuantumSculptures.pdf) (accessed February 4, 2010), 2

<sup>21</sup> Kit Bradshaw. "Sculptor mixes physics, art in his creation for Scripps." *Sun Sentinel (fort lauderdale)*, March 11, 2009, sec. B.

<sup>22</sup> Vince Patton. (2008, December 18). *Art Beat Oregon* Portland: OPB TV, 2008

<sup>23</sup> Kevin Max. "Quantum Man." *1859 Oregon's Magazine*, Winter 2009, 25

<sup>24</sup> Patton.

Andreae nearly two years to assemble all 1336 pieces inside the twelve-foot diameter stainless steel ring.<sup>25</sup> Each length of pipe's cut and weld had to be precise or the Angel would not take proper shape.

*Angel of the West* is impressive to behold. The sheer size of the sculpture, together with its stainless steel form show a strength and beauty reflected in the subject matter. The title of the sculpture is derived from Voss-Andreae's belief that "antibody molecules are like an army of angels"<sup>26</sup> and also openly references the *Angel of the North* sculpture in England by artist Antony Gormley. The content of the sculpture itself is a tribute to both the research and science of Scripps Research Institute. As with any Voss-Andreae sculpture, the visualization of the science is truer in spirit than in function, but the final piece communicates exactly what it needs to: scientific research and the human antibody are immensely important to life. Voss-Andreae's work is a testament to the combination of art, technology and science working together.

Jansen, Lang, and Voss-Andreae are all incredible artists and each is forging new paths in their given sub genres of sculpture. Theo Jansen's *Strandbeest* walk the beaches of the Netherlands with a distinctive gait thanks to genetic algorithms applied through computer technology. The complexity of Robert Lang's origami sculptures are the direct result of applied mathematics and technology colliding with an age-old art form. Julian Voss-Andreae's sculptural work with human proteins and other scientific data would not be possible without the modern technology he is able to employ. Each of these three artists apply math, science and technology to achieve what once may have seemed impossible only a century ago.

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<sup>25</sup> Bradshaw.

<sup>26</sup> Ibid.

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untitled]Protein Sculptures: Life's Building Blocks Inspire Art." *Leonardo* 38, no. 1 (2005): 40-5. OmniFile Full Text Mega, WilsonWeb (accessed February 5, 2010).

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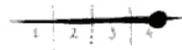
Patton, Vince. (2008, December 18). *Art Beat Oregon* Portland: OPB TV, 2008



Figure 1. Theo Jansen, *Animaris Currens Vulgaris*. 1993. 1.4 x 2.1 x 2 m. In *The great Pretender*. (Netherlands: 010 Uitgeverij, 2007)



Ik moet iets vertellen over de anatomie van het beestje. Het bestond slechts uit vier delen, vier segmenten. In onderstaande tekening zijn alle segmenten recht.



Maar ze kunnen ook krom zijn: krom de ene kant op of krom de andere kant op.



Figure 2. Theo Jansen, *Animaris Lineamentum*. 1990. In *The great Pretender*. (Netherlands: 010 Uitgeverij, 2007)

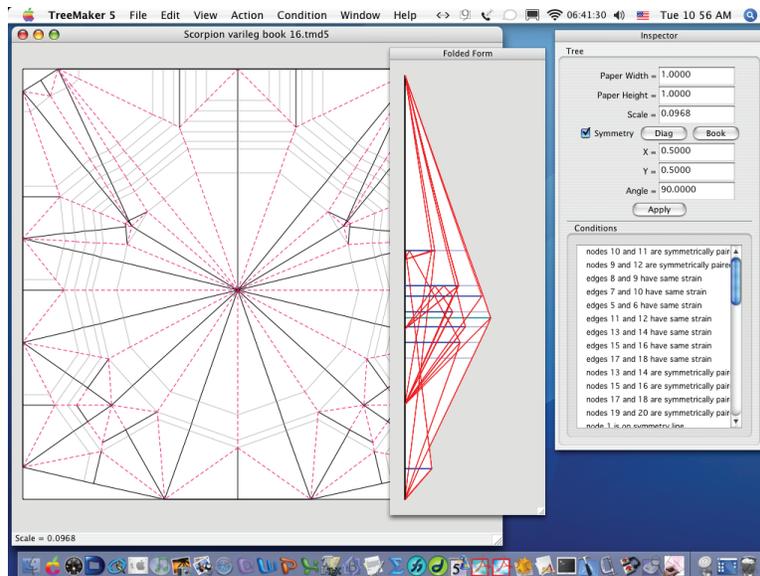


Figure 3. Robert Lang, *TreeMaker 5.0*. 2006. In *Robert J. Lang Origami*. <http://www.langorigami.com> (accessed January 24, 2010).

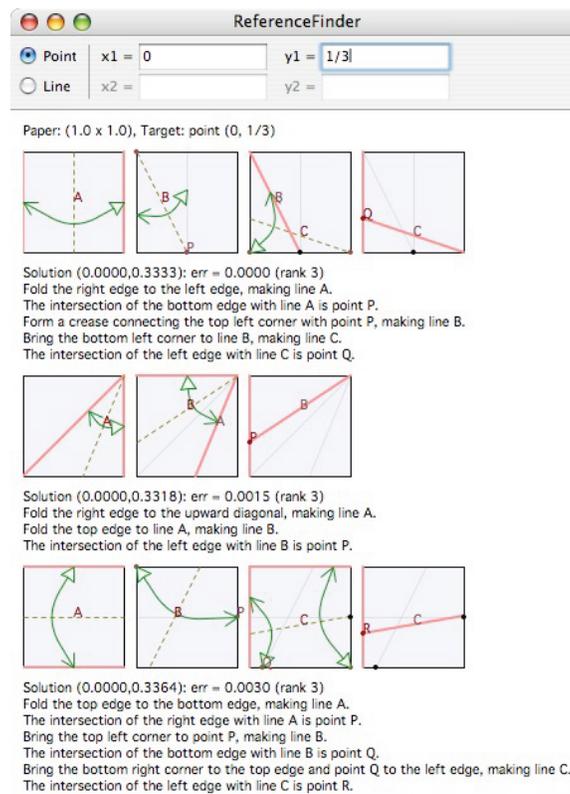


Figure 4. Robert Lang, *ReferenceFinder 4*. 2006. In *Robert J. Lang Origami*. <http://www.langorigami.com> (accessed January 24, 2010).



Figure 5. Robert Lang, *Rattlesnake*, opus 539. 2008. 8". In *Robert J. Lang Origami*. <http://www.langorigami.com> (accessed January 24, 2010).



Figure 6. Julian Voss-Andreae, *Angel of the West*. 2008. 12' x 12' x 4'. In *Julian Voss-Andreae: Science Sculpture*. <http://www.julianvossandreae.com> (accessed January 24, 2010).