

Dancing With Fractals and Antique Snowflakes

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What makes musicians compose to the rhythm of 1, 1, 2, 3, 5, 8...? What sort of world has puppets pulling the invisible strings of human dancers? Can 500-year-old snowflakes come back to life, floating down on a darkened indoor stage? Can an animated fractal keep pace with the motions of a live dancer? Do poems grow on trees? What is the perfect golden ratio of motion compared to thought? By what alchemy does mathematics become poetry?

Strange and wonderful things can happen when scientists, dancers, musicians, and digital artists try to speak each others' languages, as they did in a recent collaboration between the Winston-Salem Alban Elved Dance Company and the Wake Forest University Department of Computer Science. "Fibonacci and Phi" was the result – a mixture of mathematical concepts, computer technology, music, dance, poetry, and digital imagery that illustrates the synergy that artists and computer scientists can find in each other's presence.

The production was gratifying on many levels. On one level, it was a continuation of the Alban Elved's Free Space series, an experiment that teamed dancers and scientists to see just how well they can talk to each other, and what they might create if they try. The first production in the series was a collaboration with scientists from Duke University, where the technological part of the performance centered primarily on the use of infrared cameras to project images of the dancers from multiple angles. "Fibonacci and Phi" moved the collaboration to Wake Forest University and extended it to encompass a 1 and ½ hour performance involving parallel computation for real-time navigation through a fractal, digital poetry, 3-D and stereo animation, and audience interaction through handheld computers.

On a second level, the performance was a gratifying opportunity to take audience members from their natural territory – whether it be art or science – and entice their imaginations or intellect to consider a world they customarily find strange and incomprehensible. The thematic approach of combining math, computer science, and dance was well-received from the moment the project was announced, capturing the interest of both the artistically-inclined and the mathematically-minded. Audiences seemed intrigued with the concepts of “Fibonacci and Phi” and opened themselves to modern dance along with the complexity of mathematical concepts – curious about something that was new to them, and attracted to the new by its association with something they felt comfortable with.

On another level, we – the computer scientists involved in the production – found the pressures and challenges of a live performance a refreshing change from our quiet offices and isolated research. Rather than publishing a scholarly paper to be read only by a small specialized audience, we were called upon to find fast, creative solutions to problems that had to be “ready for prime time.” The “fractal duet,” for example, involved animating a fractal in real-time. As dancers moved through laser beams aimed across the stage, they triggered a midi signal sent to a desktop computer backstage. The signal was then forwarded to a fractal-generating program running on a Linux cluster five miles from the theatre in downtown Winston-Salem. With a gigabit Ethernet connection all the way to the cluster, 16 processors dividing the work of the Mandelbrot fractal computation, myrinet communication among the cluster nodes, run-length encoding of the pixel data, and a fast graphics card on the desktop, it was possible to recompute the fractal more than five times per second. The fractal was computed at a resolution of 1024×768 and projected at a height and width of 10 feet by 25 feet on a screen behind the dancers. The result was a dramatic interplay between the pair of dancers navigating through the fractal and finally zooming in at top computational speed.



Figure 1. “Fractal Dance”

All of this fast computation and high speed network communication would have been lost on the audience without some explanation. In truth, it would have been possible to create a movie of the animated fractal rather than animate it in real-time. The

result would have been just as visually impressive to the audience, but that would have missed the point – and the fun for the computer scientists. The dance production was an opportunity to illustrate the wonders of cutting edge computational speed and network technology combined with interesting mathematical concepts in a way that scientists and non-scientists alike could appreciate. A five-page printed program for the performance was thus an important part of the evening’s experience, giving explanations – through poetry and prose – of Fibonacci, Phi, and the technology underlying the performance. Concepts of Fibonacci and Phi were also explained in voiceovers during some portions the dance, the voice creatively edited through digital audio processing.



Figure 2. Illustrating the proportions of Phi in the human body

In addition to the fractal dance, the program described the other major segments of the performance. In “Dancing in Virtual Snow,” 3D anaglyphic animation techniques were used to create a snow scene in which dancers performed, viewable by the audience with 3-D glasses. With the stereo visual effect, the snow appeared to be falling on the dancers, in front of the stage, and behind the screen, expanding the dimension of the performance space. To add to the beauty of the piece, the digital artist incorporated “antique” snowflake shapes drawn from the collection of Wilson A. Bentley, who in 1885 was the first person to photograph a single snow crystal by fitting his bellows camera with a microscope. Bentley’s snowflake photomicrographs were texture-mapped on simple planes and computer-animated to tumble and fall like natural snow amid the other stereo-projected flakes.



Figure 3. Looking at virtual snow with 3-D glasses

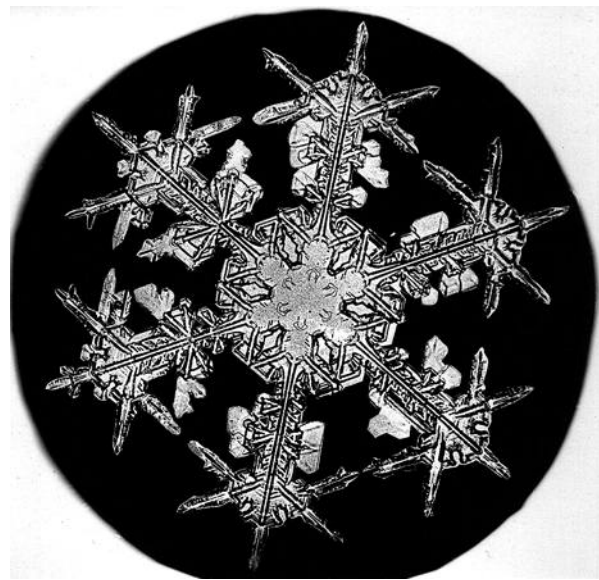


Figure 4. A snowflake from the 1885 Wilson A. Bentley collection



Figure 5. "Dancing in Virtual Snow"

In another piece, two 3D mannequins led a dance with human partners. The dancers were positioned between a back projection screen and a front projection scrim, with the images of the mannequins visible to the dancers on the front scrim. Two other dancers were stationed at a computer at the rear of the stage, operating a joystick that controlled the movements of the computer mannequins. In a sense, the human dancers became the puppets, imitating the motions of the computer mannequins. The mannequins' movements were based on motion capture data, but given an original twist – the upper and lower bodies of each mannequin were programmed to move independently of each other. Each of the upper and lower bodies could dance forward or backward in its own timeline and at its own speed. Thus, the interactive dance explored a nonlinear re-creation of dance phrases by deconstructing and recombining pre-choreographed movements in real-time into new forms of expression.



Figure 6. "Dancing With Mannequins," with saxophonist in foreground and dancers manipulating the mannequin via joystick in the background

In “Picnic Under the Fractal Tree,” the idea of self-similarity in natural forms was explored poetically. A simple fractal tree was constructed in real-time and projected on the stage. The tree’s growth began with one trunk, which then split into a random number of branches, each of which repeated the same process of splitting, continuing for a random number of iterations. Then each twig of the fractal tree sprouted a leaf that took the form of a word or phrase. Some of the words were taken from a poem written by the programmer. Others were supplied by audience members, who were asked to contribute their words and phrases to a collective poem before the performance began. Some of the words were written by hand onto a handwriting capture program on a notebook computer, to make it easier for audience members to recognize their own words when they appeared on the tree. Each fractal tree randomly selected words from the collection for its foliage. When a fractal tree had grown all its word-leaves, it then began to shed its foliage. Some leaves dropped from the tree, and some did not; some words remained on screen longer, and some appeared for a shorter time. The idea was to entice audience members to follow the words as they floated to the ground, in this way constructing an original poem. Each person could construct a different poem by following different words in a different order.



Figure 7. “Fractal Tree of Poems”

In addition to the fractal tree, the audience had other opportunities to interact with the performance. Selected members were provided with hand-held computers before the performance and were invited to type their thoughts and comments into the computers, to be projected on a screen to the left and above the dancers. “Creative” comments were encouraged, and the most interesting comments were sent through for projection by a human moderator.

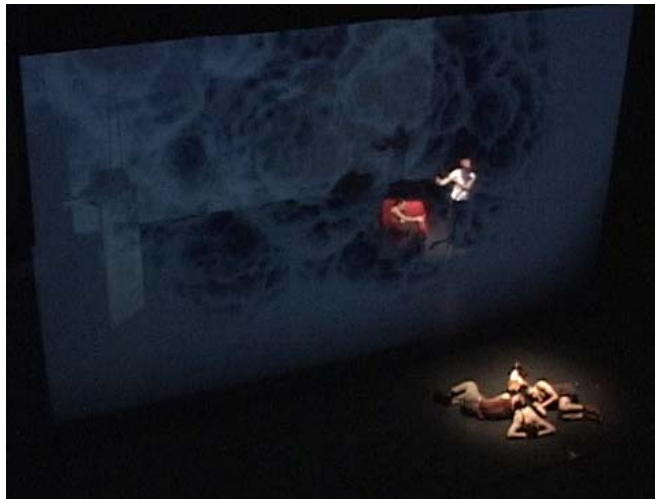
Computer science students contributed some of the digital art for the dance production. The performance opened with a montage of digital images intended to capture the variety of human experience, including natural expressions of the Fibonacci sequence and manifestations of the golden ratio in nature and art. This visual panoply foreshadowed the figurative language of the poem “Phi” as well as the visual setting of later dance pieces – for example, the night sky fractal superimposed on the pupil of a cat’s eye, the self-replicating geometry of a coastline, the graceful curves of a nautilus

shell, or the natural fractals of ferns and cauliflowers. The montage also introduced the dance production's theme.

*What are these haunting messages
Coded in cryptic languages
Through sights and sounds and senses
Speaking to us without words?*

*And how do we decipher
The beauty as it strikes us,
By saying it or counting it
Make it finally our own?*

(The poem in its entirety is given below.)



*Figure 8. An image from the opening montage:
the fractal form of a cauliflower head, digitally altered*

A second student-contributed piece was a logarithmic spiral reflecting the proportions of Phi, drawn by tracing through the diagonals of squares whose sidelengths follow the sequence 1, 1, 2, 3, 5, 8, The spiral formed a backdrop to a dance choreographed with the golden ratio and music echoing Fibonacci intervals and cadences. The spiral was first projected on the back screen and then painted with natural fractal forms. It then was transformed into the face of a sunflower, and finally spinning off into space as described in the poem.



*Figure 9. The logarithmic spiral and “Spiral Dance”;
comments from audience show on screen overhead*

The final dance number in the performance was backlit by what we called our “night sky,” a Julia fractal whose shape and colormap were designed to resemble a galaxy of stars. As opposed to the real-time animation of the fractal dance, this image was built from 2000 image files created by a fractal-computation program and compiled into a Quicktime movie. While the dancers performed their final aerial maneuvers and the last lines of the poem “Phi” were read, the night sky fractal was set in motion drawing the audience into its infinite self-similar detail and slowly swallowing the performance in its spiraled black hole.

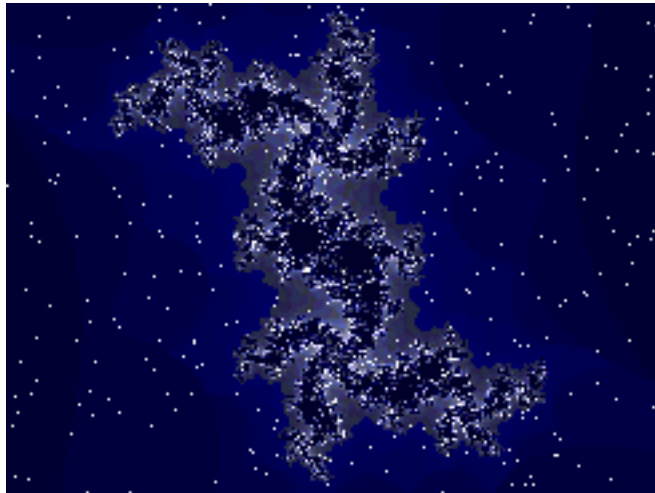


Figure 10. “Night sky,” a Julia fractal

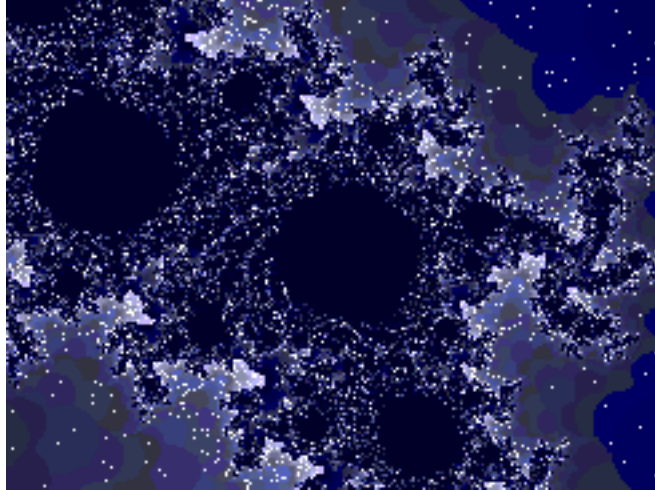


Figure 11. Zooming into the night sky



Figure 12. Closing “Night Sky” sequence

“Fibonacci and Phi” illustrates the kind of interesting work that lies at the intersection of computer science and art, an interdisciplinary area where “publication” can be in the form of a live performance. Digital media is an exciting and growing area, with enough science and art in it to attract audiences from either side – enough to ignite the creativity of mathematicians, scientists, and technicians while at the same time engaging the intellectual curiosity of artists and humanists. Computer scientists should keep their hold on a piece of the action in digital media and the entertainment arts, for the sake of all that they have to give to it, and for all that it can give back to them in return. Computer scientists can lend scientific rigor, precision, and mathematical understanding to digital media. In return, they are paid back with the inspiration that comes from exercising one’s creativity in front of a live audience, weaving the wonder of science through the poetry of human experience.

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Phi

What are these haunting messages
Coded in cryptic languages
Through sights and sounds and senses
Speaking to us without words?

And how do we decipher
The beauty as it strikes us,
By saying it or counting it
Make it finally our own?

Who hears the golden music best,
Who sees with clearest vision?
And can they tell me what they see
And write down every note?

A child has eyes still bright and true
An ear open to voices.
A child hears shouts of tiny "Whos"
On dust specks in the air.

A child knows worlds hold worlds inside
Each world leads to another
And angels dance on heads of pins
When you reach infinity.

But children don't have words for this
And insufficient numbers
And as we age we want to say
Or count what we have known.

The ancients mathematicians sought
A language most eternal
And found in pure proportions
A number timeless and divine.

The golden ratio they called it
And Phi in Greek we named it.
And everywhere we find its mark
In nature and in art.

I see a message etched
In a ragged rocky coastline
And the pattern is repeated
In the ripples at my feet.

A fern unfurls its growing leaves
Like nature's own fresh fractal
So I paint a fractal of my own
To find the world inside.

I try to read a message
In the face of a sunflower
But I'm blinded by the spirals
Spinning left, and spinning right.

The spirals leave my dazzled grasp
A galaxy is born
And sends to me through heaven's
time
A metaphor of stars.

A message whispers softly
In the angles of a seashell
And calls my soul to trace a curve
Down paths that never end.

I am told that these mute messages
All have Phi locked within them.
What is this magic number?
And what secrets does it hold?

We cannot write the number,
So irrational by nature.
Never ending, always changing
As it steps toward the sublime.

What would happen if we could
Know the endless perfection?
Say in words and in numbers
What we don't yet understand?

If we mark the musical intervals
With infinite precision
Can we make a human symphony
From the harmony of the spheres?

If we trace the seashell's spiral
Down endless perfect angles
Will we finally find the center
And meet the eye of God?

We cannot take the measure
Of Your exquisite beauty
Though it's woven in the fabric
Of our world and our flesh.

We cannot say Your name
Though it's written in the sky
Still we silently rejoice to read
The messages You send.

Jennifer Burg, October 2003