ARIZONA STATE UNIVERSITY

Real-Time and Networked Visual Displays

Data Streams in Art Applications

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In a world that has become vastly more complicated, multi-layered information systems have an increasingly compelling impact. Access to complex, interactive data is necessary to informed thought and global action. Utilizing computer modeling, aesthetically-driven prototypes for displaying numerical data provide fresh viewpoints, promoting deeper awareness of living institutions and developing trends. Visually compelling information lends clarity to the grand cycles of nature and human creativity, while revealing intimate perspectives on daily life. This versatile project emphasizes artistically sophisticated live data streams. Evolving artworks allow for a multitude of display options; images can be projected onto architectural or sculptural forms, displayed in buildings, terminals, and offices, and accessed via PDA's and the web. Artists, scientists, and other experts will research data to be utilized in the creation of responsive visualizations.

The displays seek to provide the technological infrastructure to 1) sustain the ability for creation of evolving information forms as modes of presentation advance 2) allow for live visualization of dynamic data streams relevant on local, regional and global levels, and 3) open up the possibility for imaginative uses of data to experts pursuing different methodologies. A robust, scalable framework for adapting data visualizations to various platforms will be implemented through utilization of open, standards-based software libraries. A central server will aggregate public syndication feeds of data related to pertinent subject areas. Through a web syndication protocol, streaming information will be used as the source of data for display. Server resources open to the public as well as research communities can aid in the study of current issues through artistically and contextually accurate visualization. The project will help detect long-term patterns in the global environment! , enhance sensitivity to the quietly functioning aspects of our surroundings, and open expanded avenues for collaboration between the arts and sciences.

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REAL TIME AND NETWORKED VISUAL DISPLAYS

Overview: In a world that has become vastly more complicated, we are only subtly aware of the multi-layered systems impacting daily life. Information from these systems can be visualized in new ways using real-time computer modeling. Aesthetically-driven information models for displaying data provide fresh viewpoints, promoting a deeper awareness of living institutions, cities, and natural environments.

Recent research investigates the development of conceptually sophisticated sculptural and virtual surfaces containing embedded numerical data as texture. The project develops a readable way of knowing the living functions of the environment through data, which recording agencies may analyze and report only statistically. When visualized, this data provides new ways of seeing, offering intuitive, tactile models of the history and structure of living institutions and natural phenomena. These can include urban function (i.e. power usage, water flow, and traffic density), resource consumption, and larger global cycles. The creation of original, aesthetically driven methods to display data that is normally hidden, but numerically available, can aid in public understanding of the complex attributes of large natural and human-made systems. Statistical information, interpreted in ways that are aesthetically challenging, can result in visually appealing, understandable models. This endeavor includes continuing development of computer programming and open-source technologies, allowing the direct visual translation and three-dimensional digital production of data streams through insertion of drawing and sculpting capabilities and an increased capacity to apply numerical 'noise' to more complex surfaces in real time.

Current work in digital sculpture and imaging involves the translation of numerical data streams to two and three-dimensional displays. Using computer modeling and stereo-lithography, it is possible to visualize not only normally viewable objects but other types of information as well. *Inside Information* and *Solar Streams* (2002-3, M. Neubauer, S. van Note, and T. Ingalls) are groupings of digital prints and sculptures that visualize long-term factors solar wind and sunspot activity from NOAA satellites. *Heliopolis* (2004, M. Neubauer, R. Khonda, S. van Note, and J. Stewart) presents ongoing municipal data on the city of Phoenix, Arizona and its surroundings through monumental animations of visualized number streams projected on large buildings. Viewers are taken on a sensory voyage through a series of numerically based objects. The *Politics of Water* (2004-5, M. Neubauer), a series of digital prints, examines water issues in the Sonoran desert through visualizations of flash floods, riparian stream levels, canal flow, and annual water usage. A public art project, *The Digital Shoreline* (2004-5, M. Neubauer) focuses on university and community data, while the ongoing *Global Streams* (M. Neubauer, 2007-10) examines a range of globally significant geophysical data sets through prints and rapid prototypes.

Visualizations using unique lines of proprietary numerical information have also been developed: iron foundry furnace output, metallurgical iron-stream testing, telecommunications call volumes, glucose levels in the bloodstream, Geological Information Service climatological data, airport runway, decibel, and stage recordings, municipal water statistics, university enrollments and class meeting times, attendance, and atmospheric pollutant documentation. These smaller projects also consist of 3D screen shots developed into large-scale digital Lambda prints, sculptures developed from small prototypes, as well as animated forms in 3D environments.

This artist-based approach to visualizing long streams of numbers has significance in its potential for developing unconventional ways of generating and evolving new sculptural forms; its interdisciplinary teaching potential; its public art possibilities; and its ability to interpret any manner of data in a visual and tactile way. In addition, it has implications for the public perception of long-term global and urban cycles. It holds promise for public or corporate art projects in which a visualization of data can play a significant role.

The underlying research behind this creative work investigates the development of conceptually sophisticated surfaces containing 1) *Embedded information as texture* 2) *Capture of live or near real-time data streams for virtual sculptures that constantly mutate in response to input* and 3) *Projected numerical animations as surface treatment*

The creation of aesthetically driven methods to visualize and display data that is normally hidden, but numerically available, can aid in public understanding of the complex nature of large natural and human-made systems. The project seeks a readable way of knowing the living functions of the environment through data that recording agencies analyze statistically. These incoming numbers, when visualized, can provide new ways of seeing information, offering intuitive and tactile models of the history and structure of living institutions, urban function, resource usage, and geophysical cycles.

An Arizona State University Institute for Studies in the Arts Research Grant, ASU's Herberger Institute for Design and the Arts funding, Tempe (AZ) Cultural Services, and the Phoenix Office of Arts and Culture have supported a sequence of projects. Residencies at the John Michael Kohler Center for the Arts, the Scottish Sculpture Workshop, the American Academy in Rome, the Tyrone Guthrie Centre, and the Vermont Studio Center have allowed time for research

and development over the past ten years. The images accompanying this paper illustrate the results of some the number streams thus far utilized in the work.

Static models**:** The first core aspect of the work involves surface development of static data on three-dimensional machinable models and prototypes. These models focus on archived data, which can be adapted to drive the development of sculptural surfaces. Streams of data, manifested as textural activity embedded into artworks, become a type of permanent, visual history. The sculptural forms and Lambda prints from computer prototypes resulting from this work have information-bearing surfaces created from numerical records. Statistics, interpreted as dimensionalized graphing or elevation mapping, are manifested as textural activity, becoming part of the matrix of the piece. While it is possible to cover completely cover an illusionary 3D surface with texture or pattern, as in bump and surface mapping, this project endeavors to embed the data physically, as vector information, onto volumetric surfaces.

A simple computer program developed for the project enables the direct translation of numerical data streams into machinable vector line files. Graphs created in *Excel* detect periodicity, and predetermine the look of the line and the number of sections it is to be broken into for programming. Any string of numbers is convertible to a vector profile, streamlining data conversion for all linear graphs. The vector lines, initially created as lathe profiles, turned at 90, 180, and 360 degrees, become sculptural. Three-dimensional visualizations and prototypes of long-term historical data are possible.

Numerically dense graphs, which often reveal the somewhat rhythmic backdrop of long-term cycling of events, demand a more complex approach. These more intensive data sets provide several interrelated variables to work with. When translated from number streams to line graphs, the statistics reveal long-term fluctuations. Patterns far larger than the human lifespan, or too deeply complicated to see entirely in a linear way, become visible. This data is built into the dimensional nature of the NURBS model during the design stage. Succeeding models interpret data into an XY terrain grid with data as elevation, and time blocked out into segments as length and width.

For example, an early terrain model used twenty-two 11-year sunspot cycles to produce a machinable landscape. The general pattern of the information became apparent. One side of the landscape appeared mountainous (the active range of the cycles) while the other was flat, save in some outlying aberrations. This approach poses a method for using time as x and z factors and data as the y factor. Further development produced an adjustable, three-dimensional mathematical armature, providing volumetric surfaces for visually coded numerical information.

The scope of the project soon demanded the construction of a more infinitely variable mathematical structure, which could readily accept the application of information-bearing surface detail. There were several stages in this process. The first step was to apply the data elevations to a spirals and helixes. They were expanded laterally, smoothed to the base plane from a central apex to form a ribbon rather than a line, and applied to a cylinder and a cone. The first prototypes were conical ribbons, which were not seamed together. The length of the data was divided into separate numerical segments and stretched to fit the cylinder or cone. The helical seams were brought into proximity for actual reverse engineering and prototyping. Next, two ribbons of data were stepped at 180 degrees on an attempt to create a more cohesive surface, though one which was still open at the top and the bottom. The rapid prototype resulting from this was a cylindrical iteration of the sunspot data, with each 11-year cycle described as one loop in the helical movement of data up the surface. The 11-year peaks are readable vertically, while the entirety of the 22 x 11 year cycle is readable frontally. The next progression was to apply the data to a parabolic curve, and ultimately to a cubic Bezier curve. Additional programming proportioned any kind of data in any number of segments upon a curved form. The first program applied a data to mesh approach, while the next two developed a fixed Bezier curve formula. The first was used to create points; the points were used to make the surface. The next program developed the texture perpendicular to the curve while the final iteration read the texture from the baseline, or central axis in a more natural way. The texture varies proportionally along this fixed Bezier curvature.

The intention in image and prototype production is to adhere to an art aesthetic but to keep the underlying forms purely math-driven and true to the original line graphs from which they were created. Several simple computer programs aid in the process of conversion of number to form. The first of these programs manipulates control points on the Bezier curve in order to alter its proportions. The next program provides an interface to articulate these armatures geometrically, while additional programming allows the artist to manipulate the Bezier curve more intuitively, stretching, swelling, or elongating it. These 3D templates begin to provide a library of mathematically armatured surfaces upon which research and artistic exploration can progress, with application of data as informational texture, inside and outside, or on a helical, as well on a pole-to-pole basis. The amount and density of data applied to the size of the volume's surface changes the depth and angularity of the texture. Depending upon the ratio of data to surface, and how the computer program interprets the data, some of these objects began to bear a resemblance to patterns in nature. Colors, transparencies, atmospherics, and lighting are assigned by the artist, with the intention of revealing both the inner and outer surfaces of the objects and conveying the feeling-tone of the data. The project seeks to produce a program that is intuitive for the visual artist, which overlays a sculptural approach over a mathematically based interface, and which moves more fully into NURBS geometry. Ultimately, machinable, information-bearing vector surfaces could be applied to complex three-dimensional forms very rapidly. The nature of the statistics would have an aesthetic impact on the underlying form, while sensors could read and interpret the sculptural object as pure numerical information.

b) Dynamic Models: The second aspect of the project involves the capture and translation of real-time or near-real-time living data streams onto surfaces of three-dimensional virtual models. The dynamic models can keep the viewer informed of aspects of the myriad, complex aspects of global or urban functioning through a composite of lively, ongoing information. By creating virtual sculptures that constantly change color, texture and shape in response to numbers, or projecting moving images, animated statistics, or numerical data onto or from within sculptural form, interpretations of real-time streaming numbers is possible. Such information can move across sculptural surfaces in ever-changing illuminated graphics, fluctuating sound, and changing color. A programming interface can animate statistics and numerical data, streaming the interpreted information onto sculptural form as visual patterns, with a computer display this captured electronic information. The visual manifestations of real-time data flow across digitally modeled volumes making sculptures that have a kind of sensitivity to input. Underlying primary sculptural forms act as volumetric templates for the animated data. The developing data can spin off unexpected visual effects as information travels across the surface of the sculpture. An event plane, a line of latitude, on the sculpture could trigger alterations or mutations in the data through a mathematical cue, by either programming a shift to a different information stream (i.e. from water flow to electrical usage to traffic flow) or altering the color, pattern, or velocity of the projected animation. By inserting a logarithm into this event horizon on the dynamic models, the sculptural form can become a model of self-evolution, accessing information, which processes across the surface, enacting changes and mutations through formal, dimensional triggers. The artwork would thus be able to create its own mutations, evolving its imagery from raw data input yet remaining in a self-creating state.

The work presents a visual format of color, motion, sound, and pattern for the statistical data flows. Although these dynamic objects can exist in virtual space alone, they can also be presented in real space at a large scale. While applying real-time or archived images onto a flat screen display is already possible, a custom interface is to be developed that will directly translate incoming, live numerical streams onto dimensional surfaces in response to their unique shapes. Algorithms will alter the information as it passes the proposed event points on the 3D images.

c) Web-based and interactive formats: Collaborative work with sound artist Todd Ingalls, a Research Professor in Arizona State University's Arts, Media, and Engineering program utilizes more recent MAX 5.0 and Jitter applications and emerging open-source technologies. This work expands upon the display of dimensional forms that are continually evolving as incoming real-time data moves across their surfaces. A multitude of display options are under consideration: projection of live streaming information onto architectural or sculptural forms, displays on monitors in public buildings and offices, or single-user viewing on PDA devices via the Web.

Neubauer and Ingalls first collaborated on the *Solar Streams* project, in which Professor Ingalls inserted the already-created digital sculptural forms into a bell-modeling program. The solar wind data was sonified and made to digitally reverberate within the interiors of each of the twenty-four form. Interpretations of this sonic data became the soundtrack for the DVD version of the artwork. In 2010, Neubauer and Ingalls installed a public art project, the *Photo-Luminescent Sound Garden*, exhibited at the Scottsdale, Arizona, Civic Center Plaza Bell Tower. It consisted of six illuminated volumetric sculptures composed of 50 to 100 layers each of laser cut photo-luminescent material interleaved with edge-glow plastic mounted on light tubes. The central tubes diffused LED lighting throughout the layers. A motion sensor detected the movement of people walking underneath the bell tower where the sculptures are suspended. When human motion was detected, the objects responded, moving from a dreaming or contemplative mode to an active mode: the light tubes illuminated in a lively random sequence. They ramped down into a random slow illumination mode again if no motion was detected after 20 minutes. Late at night, the objects went to sleep, leaving only the mysterious layers of photo-luminescent material to glow until morning. The flower/radar-like shapes echoed the photo-luminescence of night blooming desert flowers. At the same time, the motion detector, through micro-controllers, also notified an audio sequence to be activated, a twenty-four hour musical sequence was activated, emulating the sound of bells in the distance, but altered electronically. This project explored the possibilities of a responsive artwork reacting to the environment through sound, motion-detection, and light. The data input in this case was the movement of pedestrians in the area.

There are three key components of research going forward, which seeks to provide the overall technological infrastructure to support the goals of 1) sustaining the ability for continued creation of these forms even as technology and modes of presentation evolve in the coming decades, 2) allowing for the display of a wide and dynamic assemblage of data streams that will remain relevant on local, regional and global levels, and 3) opening up the possibility for other imaginative uses of data streams for purposes and using methods different from our own.

To meet the first goal, the investigators seek to work with research and engineering professionals to create a robust and scalable framework for adapting art-oriented visualizations to various display platforms. Ingalls and Neubauer also seek to implement this project by development using open and standards-based software libraries and technologies. The researchers seek to collaborate with groups of scientists and other experts to develop the relevant data sources that will be used in the creation of future responsive visual displays. A variety of data sources representing regional conditions, relevant to the western United States, or pertinent to changing global conditions will be utilized.

Finally, the development of a central server is proposed. This sever will aggregate publicly available syndication feeds of data related to both the causes and impacts of geophysical and urban change. These information streams, through a web syndication protocol, will then be used as the source of data for display on the animated objects. In addition, these resources would be open to the general public as well as various research communities to aid in study of the flux and change in metropolitan areas and natural systems but also to allow for others to find new and innovative ways of contextualizing this information.

The proposed project will help detect long-term patterns in the global environment, enhance sensitivity to the quietly functioning aspects of our surroundings, and open expanded avenues for public art and visual displays. The final goal is to lend clarity to the grand cycles of nature and human activity, while revealing intimate perspectives on day-to-day life.

Summary: The project honors the kinds of sophisticated machine intelligence now necessary to keep complex systems running smoothly. It explores the application of both living and archived information streams to sculptural surfaces. It examines the capability of sculptural surfaces for developing a type of responsive intelligence through their interpretive, interactive display of numerically based images.

In a world that has become vastly more complicated, we seldom think about or take time to understand the multi-layered systems supporting and informing daily life. By helping individuals interpret their ever more complex, mediated, and changing environment from a visual standpoint, a new and more comprehensive understanding of our contemporary state is perhaps discoverable. The anticipation is that this type of artist-driven data visualization would help to focus on and clarify aspects of our current condition. Visual access to data streams can serve as a leading indicator, providing a new way of viewing all sorts of information while keeping art on the edge of technology. This visible, concrete, and tactile information can provide can new way of seeing long-term patterns and structures in our larger environment, provide new avenues for public art, and enhance our sensitivity to deep global patterns.