# Kepesian Visualization

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**Abstract**

*Kepesian Visualization* is an emerging artistic and scientific genre that is focused on planetary science and has roots in scientific visualization and environmental art. The genre produces aesthetic engagement that reveals the intrinsic beauty of geophysical systems through data discovery by means of techniques that influence perception. This experimental approach focuses on the pre-attentive state in a non-photorealistic abstract form by employing two key elements: aesthetically biased symbolic representations designed for a fast-paced transient environment and subtle player interaction mechanisms. Such visualization is made possible by highly responsive systems and commodity computers with high-powered CPUs, graphics cards, main memory, extended disk space and network connectivity, allowing pervasive access to vast data resources. The use of on-line persistent worlds in which a user manipulates geophysical systems that are normally unseen extends the user's ability to perceive underlying structure, enhances collaborative aspects of environmental agency, and provides artists with engaging new landscapes that can be interpreted and celebrated.

## Introduction

There is a growing trend in scientific visualization to integrate perceptual artistic methods. When combined with Earth system science (ESS) data and specific criteria related to the visual arts, vision, the environment, science, technology and society, the work of visualization broadens to a larger scope that is defined herein as *Kepesian Visualization*. A work has elements that are characteristic of *Kepesian Visualization* if it is based on visual art and satisfies four further criteria: it explores the primary components of understanding images, addresses major environmental problems and explores scale, enables individuals to interact collaboratively with the environment, and celebrates nature. In addition to fulfilling these conceptual criteria, the work must not only employ science and technology but treat them as having equal importance to its artistic imperatives.

In such work, Earth's environment is conceived of as a system of geophysical states heavily influenced by humans. Users of *Kepesian Visualization* combine the scientific components to obtain truths about the Earth's geophysical system, elicit beauty by observing and interpreting data through visualizations made possible by the integration the genre permits, and are moved towards environmental agency. The scientific components convey truth about the systems and beauty through observing and interpreting Earth's systems. In this case, "beauty" is achieved by a negotiation of scientific structure and aesthetics to bring forth a pure state in which one can appreciate the essential contextual idea of each discipline in addition to their union as an art genre. Such visualization uses technology as the vehicle to develop solutions and apply them for the betterment of the environment and humankind. The artistic practice both finds problems and generates solutions predominately within the artistic domain although art, science and technology are interdependent. The artistic domain is significant for several reasons: its influential nature combines its effectiveness in soliciting pleasure and other aesthetic responses, its ability to communicate non-verbally, and its related aim at a higher intelligence and deeper intuitive understanding of the problems addressed.

A selection of ideas contributing to environmentalism, an overview of relevant work in Earth system science visualization, and a description of the underlying aesthetic approach to *Kepesian Visualization* follow.

## Contributions to Environmentalism

The study of climate change was introduced by the Earth system science (ESS) community and has become a focus of major international campaigns to observe and model Earth [61, 74]. The ESS data indicate that climate change is heavily influenced by human activity [73]; therefore humans must become more aware of their impact on the environment. The added pressure of uncertainty regarding Earth's geophysical tipping point [25] - the point at which the geophysical systems might not recover stability - has created a heightened sense of urgency to engage the public in finding ways to mitigate human impact.

Understanding the environmental situation of climate change and enabling human engagement with geophysical systems involve not only science and technology but also philosophy, spirituality, religion, ethics, law, history, theory of the arts and artistic practice in addition to humanistic methods. By its very nature, the practice of *Kepesian Visualization* is concerned with *geisteswissenschaften*[1] and requires an interdisciplinary approach. A wide range of schools of thought exist in the humanities on many aspects of climate change from environmental justice to intelligent design [37]; however, since this interdisciplinary research area is so new, no significant body of work focused on climate change (as a comprehensive Earth system science) in the humanities exists. One might look to less integrated ideas in the humanities such as environmentalism and naturalism [27] or specific disciplines such as environmental art, environmental politics, environmental anthropology and environmental philosophy. There has been a significant amount of research on the relationship between humans and nature, specifically the spiritual associations around humans' reactions to and attempts to control and care for nature. In particular, much research exists on rituals and artifacts related to natural phenomena and events.

The positioning of humans to command nature was established historically by some ancient philosophies and by religions. The new ecology, by contrast, defines humans as part of ecosystems. This view supports the concepts of species democracy, species-"trans-nationalism [which is] trans-species forms of the state in which some communities are context-specific and are defined by their shared potential to suffer ecological or biological harm [19]." Environmental ideas have been well developed through such writings as those of Henry David Thoreau, the notebooks and diagrams of Aldo Leopold, and Rachel Carson's *Silent Spring* [15]. These and other writings led to the concept of "*ecosophy T*" by Arne Naess [62]. Relationships between humans and nature have been explored by an increasing number of groups, including practitioners of Deep Ecology [2, 3, 4] and Green Culture [32]. The area of Deep Ecology is especially relevant as it involves a very strong mix of humanities and centers on a conceptual model of convergent ideas from major religious groups as well as climate change science.

Practitioners of Deep Ecology approach environmental issues by using deep ethical reflection about the implications of the issues and seek just and manageable goals [75]. Deep Ecology defines basic premises contributing to cultural beliefs as those of religious doctrine (Buddhists, Christians, philosophical thinkers etc.) in comparison to integrated assessment modelers who think of human archetypes as individualist, hierarchist or egalitarian [63]. An environmental movement happens when many individuals holding common beliefs or theories form a sub-society that is motivated to environmental agency. Key tools in climate change science are models that forecast geophysical systems. The models use climate change scenarios (stories) based on a projected sequence of human and geophysical behavior. Climate change scenarios employ archetypes based on a concept of the culture in which they live and cull parameters associated with the society's behavior, which are then used (along with other non-human induced factors) to "force" geophysical models that produce simulations. In this way, certain value systems and beliefs resulting in behavior affect the forecasts of Earth's environment. The scenarios being acted out through simulation over long periods of time are based on assumptions about the embedded culture regarding factors that may change the climate, such as the use of fossil fuels or the disposal of waste.

Parameters based on qualitative human characteristics, which have been used in climate change scenarios and integrated assessment models to forecast the geophysical future of Earth, matter greatly. These parameters define an archetypical society and the models in which they are used simulate possible changes in the Earth system, according to that specific archetype. Each environmental stakeholder (environmentalists, religious groups, governments etc.) can be defined as an archetype if its values and philosophies are well understood. The results of the simulations are at the core of the battles being fought over the adoption of environmental policies and regulations because major differences have arisen in the assumptions made in defining the archetypical society and its impact on the environment. Therefore the cultural context of the human impact parameters selected to force simulations is closely linked to philosophical and scientific concepts.

[1] [Geisteswissenschaften] literally translates as "sciences of the spirit or mind" and is associated with early nineteenth century German philosophy (initially the likes of Hegel), that gets developed in the later nineteenth century by the likes of Wilhelm Dilthey to read as something like "human sciences" as opposed to, or at least not reducible to, social sciences. [23]

## Kepesian Visualization

Motivated by environmentalism, and certainly influenced by Carson and Leopold among others, Gyorgy Kepes (1906-2001) articulated paradigm-shifting environmental imperatives and called for art "...toward the development of imposing features that may serve as symbolic forms of man's attempt at collective self-regulation" [44]; the attempt focused on the visual arts and urban planning. Specifically, *Kepesian Visualization* seeks this higher purpose of art to enhance humankind's appreciation, and understanding, of the environment. This artistic practice brings forth new ways to provide not only symbolic forms, but also art works that become *the vehicles* by which humans might realize collective self-regulation. Kepes and his scientific and engineering collaborators believed that science (truth) and technology (mechanisms) were the keys with which artists and their audiences could unlock the fundamental laws of nature and realize its intrinsic beauty in addition to improving the human condition. By formalizing this unique artistic practice, Kepes discovered a *co-domain* in which art, science and technology shared many of the same subjects, goals, methods and results. This co-domain has until now been difficult to decipher as there are many different discipline-specific handles as well as unarticulated analogies.

Imagine a dimension in which one travels on the crest of waves, and also upward and around in projection pursuit, while pulling threads along until a fabric is woven that appears to be molded onto the surface of a chaotic n-dimensional shape. This shape, when examined, makes most sense if studied "before words" can explain it. "Projection pursuit" is a phrase in scientific visualization which means that one's point of view is constantly changing as one visually pursues a model. It usually refers to pursuing a model that is changing it's dimensions. For example, one would start out seeing a point then a line. In doing so, one might zoom forward over the line to inspect its dimension. Each time a dimension is added the model is examined while the viewer is in constant motion. The focus point is on the model and it never leaves the model to wander off towards the horizon. Working in *Kepesian Visualization* is similar to projection pursuit. One starts out working with ESS data to visualize its properties and to analyze its individual values. The next phase, or dimension, is understanding the data's major characteristics and prominent features. Afterwards, understanding forecasts (simulations) and models follows. It is in the interaction with dynamic global data that one expands one's understanding of the environment beyond a local view to one of an Earth *system*. Understanding how one is interconnected with Earth's geophysical systems may come as an epiphany as if suddenly understanding a complex mathematical model while in projection pursuit, or the understanding might occur after many engagements with the data. The challenges for the artist are to create an experience that magnifies appreciation of, and a sense of beauty in, the environment; and to elicit a sustained desire to mitigate impact on natural systems. If the audience does change their behavior and the environment responds positively then the audience would have acted collaboratively and completed the cycle which *Kepesian Visualization* presents as its venue.

The work of such artists focused on complex natural phenomena has transitioned into a new scale, time and phase in which the lives of such entities as butterflies and jet streams have equal importance, and mountain-top philosophers find a *weltanschauung*[2] in expanded views of Earth made possible by instruments on Earth observation satellites. This realm is the world artists have inherited and learned to see, a world that requires new tools in order to mold genres, deeper understandings of cybernetic systems and geophysics in order to identify problems, and new disciplines in order to communicate them. What lies ahead are core mechanisms being revealed and eventually translated into part of the artistic process.

Foremost among these techniques and methods, the ability to observe, model and simulate a range of planetary systems has new relevance in materializing Kepes' unique artistic imperative. As stated earlier, a work has elements that are characteristic of *Kepesian Visualization* if it is based on visual art and explores the primary components of image understanding, addresses environmental problems and explores scale, enables individuals to interact with Earth systems collaboratively and it celebrates nature. Finally, the work advances *Kepesian Visualization* in significant ways if it provides a global experience, commands a greater scale (both scale of artifact and scale of content), incorporates immersion through responsive technologies that are better able to interact with nature, and integrates scientifically robust dynamic data such as observations and climate models. In this regard, the work presented herein (Figure 1: Kepesian Moment) strives to fulfill Kepes' vision for a better society, builds upon his well thought out de-constructive techniques, and confronts one of the major societal themes of our day, the environment.

[2]A comprehensive conception or apprehension of the world, especially from a specific standpoint. [81]

## Toward Works in Kepesian Visualization

The origins of *Kepesian Visualization* are in visual studies, landscape painting, post-modern sculpture, environmental art, and new forms of Earth art. Much has been written about Kepes' approach to visual studies. Kepes [42], David Marr [57] and Semir Zeki [86] provide a continuum of visual theory relevant to the exploration of visual arts with ever-increasing accuracy. Common to their theories are the attributes of primal vision: motion, contrast, form and perspective (direction). These attributes can be seen in the perceptual techniques used in ESS visualization by Healey and Enns [30], which illustrate the major features used by biological vision systems to capture visual attention and identify what is being seen. These cognitive functions have been observed to be most active during the pre-attentive state [29] and are well suited for communicating the properties of geophysical systems in transient spaces.

In searching for a lineage, from landscape painting to ESS visualization, through the art, science and technology (AST) genres for depictions of geo-systems one might consider Leonardo da Vinci's *Hurricane over Horsemen and Trees* (*circa* 1518) and Mark Whitney's *Leonardo's Deluge* (1989); Turner's *Snowstorm: Hannibal and his Army Crossing the Alps* (1812), *Shade and Darkness - the Evening of the Deluge* (1843) or *Light and Colour (Goethe's Theory) - the Morning After the Deluge* (1843); most impressionistic painting, such as van Gogh's *Wheatfields under Thunderclouds* (1890) or *Wheatfields with Crows* (1890); and William Ascroft's watercolors of skycapes painted between 1883 and 1886 [79]. Recent experimental research in scientific visualization has produced techniques based on those used by the impressionists, for example, the application developed for weather data patterns over the United States by Healey *et al.*[31]. The need to experience geophysical phenomena beyond a slice in time as a system represented in this selection of paintings is demonstrated by Ascroft and Whitney. Ascroft painted in series, sometimes every ten minutes, the effects of the volcanic eruption on the global atmosphere at Chelsea, London [76]. His paintings are among the first examples of atmospheric scientific visualization using perceptual techniques since they are based on observation and presented with artistic technique. Although Burnham discusses simulation as a post-modern sculptural method [13], he places it primarily within the domains of science and technology. Whitney is one of the first artists to use simulation to depict a geophysical system. He based his work on Leonardo's series of drawings of the Arno River and Karl Sims' interpretive particle agent software. Particles systems are a form of kinetic visualization. Kinetics have been shown to exploit motion while effectively funneling representations through to visual understanding [87], which explains the great impact of the particle systems implemented by Sims, Lums' repurposing of kinetic visualization techniques in order to gestalt structure [55, 56], and others to study vorticity [24]. In these works we see the artist's strong desire to simulate and model in order to experience and understand geophysical phenomena. We also see a long lineage of artists who practiced within the co-domain crystalized by Kepes. As Martin Kemp writes, "for Turner, scientific awe and such sentiments as poetic melancholy coexisted within a single mental spectrum." [41] Kemp described the artist as working within a co-domain of art and science while focused on geophysical phenomena. Turner, like many such artists, sought to depict the moving forces of nature [68].

A rich history of hybrid and computer art work relevant to *Kepesian Visualization* exists. In addition to the environmental art which originated at the MIT Center for Advanced Visual Studies (CAVS) including Ted Kraynick's "*Light Buoys*" [43] and Otto Piene's large scale Sky Art "*Olympic Rainbow*"[66], there are other significant works based on simulation [17, 18] and environmental related themes such as Jack Ox's work to translate landscapes into musical experiences in immersive VR [65]; Thorbjorn Lausten's "*Ozone*" and "*Meteorological Observation 2*," which are light art interpretations of atmospheric data [53, 54]; and Andrea Poli's sonification of weather data [67]. Knebusch takes us further along the path in his discussion focused on recent installation work of artists exploring human to Earth relationships [48]. In addition, there are emerging art works scaled for living habitats with global communications capabilities based on environmental data. These ambient objects also have the potential for broad societal impact [77, 84, 60]. The emergence of augmented reality and game technology offers exciting venues in which such projects incorporating the genres' characteristics can be easily constructed and rapidly deployed [36]. Thus, these new technologies, which offer artists tools with which they can produce globally scaled interactive artworks to provide audiences with collaborative experiences focused on the environment, hold the greatest promise to materialize *Kepesian Visualization* beyond the realm of scientific visualization.

*Kepesian Visualization* not only encompasses art-based approaches to environmental content, but it also includes distinct objectives: to increase awareness of human impact on nature and to motivate society to environmental agency. In contrast to dualism, a coherent concept of the Earth system by dynamic access to representations of nested interconnected sub-systems (with humans as one of the sub- systems) is one approach to enabling a more expansive relationship to Earth. The metaphor of a butterfly crossing the boundaries of resolution and scale within a specific sub-system, such as the atmosphere, is expanded as the butterfly also transverses nested synergistic sub-systems until it merges into the 'super-system' [51], or the ecosphere. This metaphor symbolizes the interconnectedness of humans and nature. To translate this metaphor into experiential visualization requires powerful computation and communication systems.

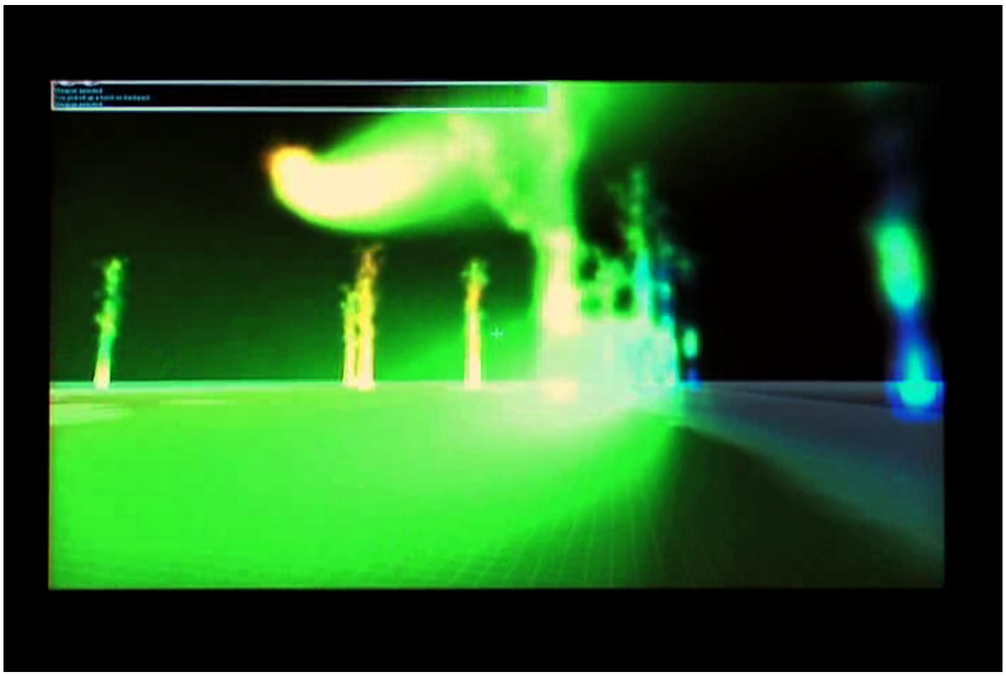

Figure 1: Kepesian Moment

## Kepesian Visualization: Interacting with Earth Data

Kepes' statement of 1972 anticipates the expansion of our horizons from a narrow concern with the *possibilities* that technology affords to the wider vision of what technology enables: "The more powerful the devices we develop through our scientific technology, the more we are interconnected with each other, with our machines, with our environment, and with our own inner capacities. The more sensitive and embracing our means of seeing, hearing, and thinking become through radio, television, and computer technology, the more we are compelled to sense the interaction of man and his environment." [45]

One technological development that shows promise for the environmental responsibility Kepes promotes appears in on-line games. Scalable multiplayer on-line games (MOGs) are an appealing and intuitive vehicle for large numbers of people to collectively experience ESS data on a global dimension as a form of *Kepesian Visualization*. Figure 1 "*Kepesian Moment*" was created as a result of player interaction with climate data. Players could move about and propagate particles that responded to data and flowed on player initiated trajectories. While the particle aesthetics are based on kinetics and reach deep into our visual pathway, the over all scene aesthetics of light and movement appear as if Picasso's light drawings [59] had been transposed by the virtual body language of game players. These engaging transient visual structures draw the player into the analysis of the forms' associated data.

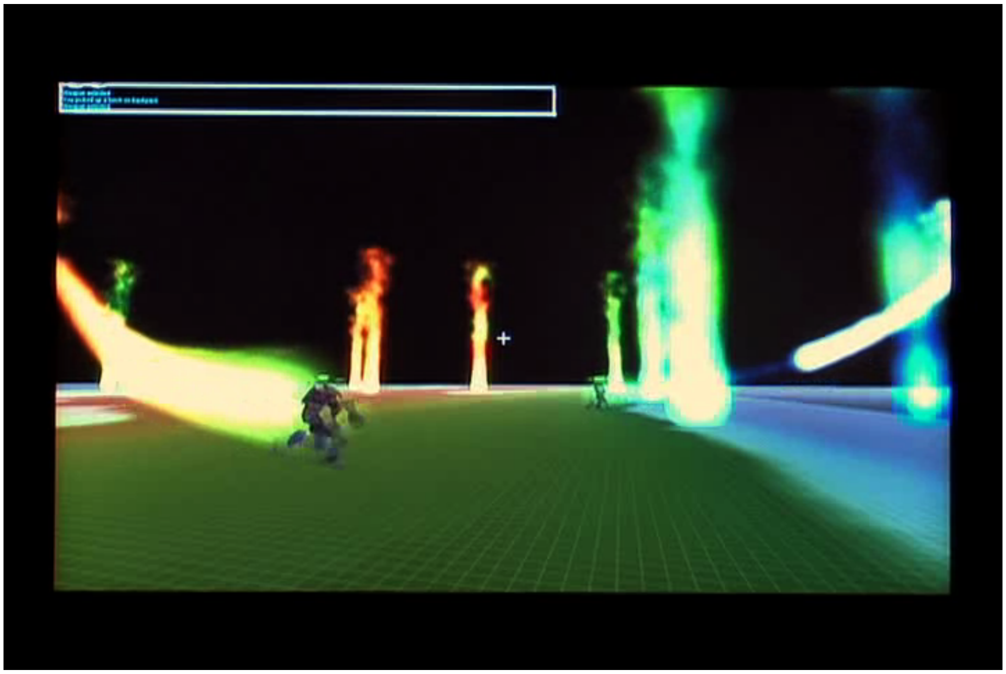

Figure 2: Encounter

This climate change game is presented in the *Kepesian Visualization: Interacting with Earth Data* installation, a multiplayer persistent world for interacting with geophysical data. The technical component aims to provide an engaging visual and aural environment in which players explore data they do not normally see or hear. The concepts of *Kepesian Visualization* provided the motivation for the development of the games' aesthetics and the underlying system the *Earth and Planetary System Science Game Engine* [50]. The project is the first known to integrate ESS model data and game engines. The use of geophysical data and models in games for scientific visualization has until now been limited by game architecture, the lack of ESS data ingest handlers, and the lack of data visualization techniques appropriate for MOGs.

The significance of the work is that the audience through their interaction with ESS data and simulations completes a loop from sensors through observations, model, visualization, individual, to the real-world and back to sensors. The medium enables confluence of not only the individual and nature, but also individuals acting collectively with nature. The goal of fostering confluence alludes to the broader goals of improving human's impact on the environment and seeks to recapture 'the lost pageantry of nature [43]' through beautiful kinetic visualization. Confluence through interaction also provides the audience with a sense of control, which is a consequential conceptual factor when manipulating large spatial structures [64]. Two crucial aspects underlying the structure of the content and interaction are that the art, science and technology are interdependent and informed by each independent element.

The type of two-way Earth system interaction through game play is unique. The concept for interaction is based on a symbiotic relationship between the natural environment and the audience. In addition to experiencing the data as a kinetic environment, a direct benefit is that the development of this technology will provide tools for collaboration and consensus-building for diasporic on-line communities. The potential for individuals, assisted by this new class of information communication system [50], to mitigate the environment will have the added benefit of contributing to the improvement of their "real-world" ecosystem as they transfer the artistic experience and reflect upon it in their everyday lives.

## Collaborative Team (*in alphabetical order*)

Gloria J. Brown-Simmons is an artist, aesthetic engineer, and at Calit2 Center of GRAVITY an Associate Project Scientist. Trained as a visual artist, Ms. Brown-Simmons integrates aesthetics with image processing, animation, simulation and interactive immersive environments as part of her work. In addition to her work in visual studies, she investigates ways to represent data, communication methods and how visualization creates an innovative approach to system design. For over twenty-five years, Ms. Brown-Simmons has applied her artistic sensibilities and aesthetics to Earth and planetary data visualization projects as a member of the technical staff at national research centers and private corporations; as an Interagency Personnel Appointee (IPA) for NASA to the GLOBE Program, White House, as the Manager for Visualization and Presentation Programs; and as a collaborator for ESS visualization research projects at national universities. She is currently exploring ESS data in game engines and investigating the possibility of integrating planetary data with other data sources through sophisticated interfaces that link individuals with major resource and service providers. Her work has been broadcast on television networks, published in international journals, and presented at international conferences and exhibitions including the Banff New Media Center, ACM SIGGRAPH; The Netherlands Design Institute's Doors of Perception; the Biennial Sao Paulo; and Ars Electronica, Linz, Austria.

Christopher J. H. Knox is a Postdoctoral Researcher, Calit2 Center of GRAVITY. Dr Knox's research interests lie in the application of scientific visualization techniques to problems in atmospheric science. His current research focuses on the development tools that will enable atmospheric scientists to rapidly explore and analyze extremely large data-sets in a visual manner, and the development of a visual computational steering system for atmospheric models. Dr Knox's previous experience and training as an atmospheric chemist in combination with his current position in computer science provide the cross-disciplinary skill set necessary for this research agenda.

Falko Kuester is Director, Calit2 Center of GRAVITY (Graphics, Visualization and Imaging Technology); Assistant Professor, Department of Electrical Engineering and Computer Science (EECS); and Assistant Professor, Department of Biomedical Engineering (BME); The Henry Samueli School of Engineering (HSSoE), University of California - Irvine. Dr. Kuester's research interests include tera-scale scientific visualization and virtual reality, image-based modeling and rendering, as well as distributed and remote visualization. His research efforts are aimed at creating intuitive, high-resolution virtual environments, providing engineers and scientists with a means to intuitively explore and analyze massive and complex three-dimensional data. In support of this work, he is currently developing real-time out-of-core visualization strategies that render massive data sets directly from external storage while requiring only small amounts of computer memory. Dr. Kuester has been active in virtual reality research for over a decade and the stringent VR requirements have served as important performance criteria for his large-scale distributed data analysis and visualization projects. He is also active in research and development of digitally enabled workspaces that support distributed, collaborative and pervasive office of the future and classroom of the future environments. Application areas of his research include simulation-based design, rapid prototyping, earth system science, biomedical engineering and command and control.

Daniel G. Repasky has a traditional fine arts background and is currently focusing on three dimensional computer graphics and new media. Mr. Repasky is pursuing the BA in Studio Art, Claire Trevor School of the Arts, UCI. His work is mostly digital, hybridizing multiple fields into a piece and concentrating on the conceptual idea portrayed through these multi-faceted means. It has been referred to as "post-modern conceptual" in style and "hybrid" because of its use of multiple mediums. He works in collaboration on research and commercial projects because he finds the team interaction and larger scope of the projects to be rewarding. He hopes to introduce new ways of making art to enable young artists who otherwise might feel limited by their existing tools, or "canvas," to explore the medium. He sees this work as his contribution to the crafting, as artfully as possible, of the digital environments which will someday become man's primary means of existence.

So Yamaoka is pursuing the PhD program in the Department of Computer Science, Donald Bren School of Information and Computer Science (ICS), UCI. Mr. Yamaoka received the Master of Science in Computer Science from the University of Aizu, Japan; and the Master of Science in Arts, Computation and Engineering (ACE) concentration, ICS, UCI. He is currently applying his background in arts and engineering to unconventional visualization of scientific data-sets in game environments.

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