Art, science, and immersion: data-driven experiences

Ruth G. West*[a], Laura Monroe[b], Jacquelyn Ford Morie[c], Julieta Aguilera[d]
[a]University of North Texas, 1155 Union Circle, Denton, TX 76203; [b]Los Alamos National Laboratory, Los Alamos, NM, 87545; [c]University of Southern California, Institute for Creative Technologies, 12015 Waterfront Drive, Playa Vista, CA 90094; [d]Adler Planetarium, 1300 S Lake Shore Drive, Chicago, IL 60605

ABSTRACT

This panel and dialog-paper explores the potentials at the intersection of art, science, immersion and highly dimensional, "big" data to create new forms of engagement, insight and cultural forms. We will address questions such as: "What kinds of research questions can be identified at the intersection of art + science + immersive environments that can't be expressed otherwise?" "How is art+science+immersion distinct from state-of-the art visualization?" "What does working with immersive environments and visualization offer that other approaches don't or can't?" "Where does immersion fall short?" We will also explore current trends in the application of immersion for gaming, scientific data, entertainment, simulation, social media and other new forms of big data. We ask what expressive, arts-based approaches can contribute to these forms in the broad cultural landscape of immersive technologies.

Keywords: Art, science, immersion, visualization, data.

1. INTRODUCTION

This panel reflects upon two emerging forces shaping science and society on a global scale: the potential inherent in integrating art and science and the emerging ubiquity of immersive systems and experiences. Each of the panelists works at intersection of art, science, and immersion in a manner that is both unique and yet representative of a broader continuum of research and creative practice that engages these forces and their applications. Our dialog will explore the challenges and value of current and future work in art, science and immersion, interleaved with commentary on the role big data and data-driven experiences might contribute towards many research domains.

The following panelist overview statements function as a starting point and context for this broader discussion.

Ruth West
Ruth is an artist-researcher. Her work is extensively interdisciplinary blending domains such as metagenomics with the arts to create immersive environments, multi-scale visualization and sonification schemas, metadata frameworks for exploring massive and abstract data sets or augmented mobile applications for environmental monitoring. Her objective is to create new knowledge and cultural forms through hybrid art-science research that blurs boundaries between disciplines in purposeful and productive ways. Immersive systems have enabled her to create new forms of interaction with massive and abstract data sets and provide new avenues for monitoring and interacting with the natural, built and social environment.

Laura Monroe
Laura is a computer science researcher with interests in the visual representation of large-scale scientific data, and how these data might be best explored by scientists and communicated to non-scientists. Her degrees are in mathematics and computer science, with emphasis on immersive systems and their use. She currently works with scientists and computer science researchers in the visualization laboratory at Los Alamos, where she and her colleagues visualize data generated from simulations run on some of the world's largest supercomputers, and use both large-scale immersive systems and desktop visualization to see the data. As a visualization scientist, her work is inherently transdisciplinary, and necessarily includes a large aesthetic component. Since the work is in an immersive context, other sensory modes besides the visual are engaged, which provide an interesting opportunity to explore and understand data via other pathways in the brain, and possibly come to new understanding of these large-scale datasets.

*ruth@viewingspace.com; phone +1 310 386-2902

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Jacquelyn Ford Morie
Jacquelyn is an artist-scientist with a wide range of research interests, from multi-sensory immersive worlds to how we are affected by our increasing use of avatars. She explores these topics from the diverse viewpoints of social science, art, psychology, philosophy and neuroscience. Her own artistic explorations over the past 25 years involve adding a human emotional component to technology-driven experiences, including psychological and mythic triggers, subconscious sensory responses such as scent and infrasound, and pre-conscious priming signals. Much of these elements are intuited by artists, and science is only beginning to realize the wisdom inherent in the artist's approach to creation. In this work, the data consists of the multi-sensory environment, objects, nature, sounds, visuals, and myriad cues below the threshold of consciousness. Added to this is the expansive bandwidth of the human in the data, adding ever shifting dimensions and richness. In her work both actual humans as well as virtually intelligent entities like virtual humans and intelligent environments become part of the full sensory data stream allowing deep personal connections between people and technologically-mediated experiences.

Julieta Aguilera
Julieta is an artist with degrees in graphic design and electronic visualization. Early on she is engaged in art, poetry, stage design and social work. Her formal career starts by studying along other designers and architects on experimental structures of space that open up action both individual and collective based on philosophy and mathematics. Further studies expand to anthropology, art history, psychology, film, theology and philosophy of science, which help inform her approach to spatial navigation. Since then, she has created CAVE environments that deal with pattern oriented and mathematically possible spaces. She currently works on and researches various immersive and interactive media along with scientists at the Space Visualization Laboratory at the Adler Planetarium. She is also a PhD candidate at the Planetary Collegium in the UK, and her research deals with transdisciplinary issues of embodiment and mindfulness, specifically how the embodied experience of dynamic synthetic environments reflects on the emergent structure of our thoughts.

2. REFLECTIONS ON CREATING DATA-DRIVEN EXPERIENCES AT THE INTERSECTION OF ART, SCIENCE AND IMMERSION

2.1 Art+Science+Immersion: Destabilization and the value of synthesis

Inherent to working at the intersection of fields is the destabilization of discipline specific approaches. As we explore the intersections of art, science and immersion, multiple layers of polarities and similarities are exposed. Here the concepts of reproducibility versus non-reproducibility form one axis, and intuition versus validity forms another. The intersection of these axes offers us a space of potential meanings within which to discuss what is the "art" part and what is the "science" part in data-driven experiences that are instantiated at the center point of art+science+immersion.

The notion of reproducibility in science, in particular the development of hypotheses and protocols that can be tested against, evaluated, iterated and refined is often perceived of as being in opposition to creative methods that focus on following a more intuitive process. Pure or serendipitous exploration also enables productive outcomes, even though, with uniqueness and virtuosity highly valued in the arts, it is often viewed as leading towards products that are non-reproducible. Yet as our panel explores this dichotomy we reveal additional layers of methodology in which intuition forms additional strata of reproducibility when recorded through writing or other forms of making. Here our dialog leads us to acknowledge the value of layering such exploration, intuition and uniqueness with reproducibility in the sciences. We also acknowledge that in the design of representational schemas, whether in the arts or sciences, the process iterates towards an audience. With an audience, the goal is not to find a single best possible representation that can exist from an entire potential universe of representations, but instead to work towards constraints and a schema that adheres to the validity of the data while also fulfilling artistic content and intent. This level of flexibility is distinct from, and perhaps richer than, more rigid criteria required by empirical methods for testing scientific phenomena in which the aim is to establish an approach that can determine the best answer ever given so far.

Jacquelyn: In some sense, intuition and other modes of artistic reasoning can be considered thought that is faster than the speed of logic. An artist is constantly weighing every decision along multiple dimensions that may not even be known by the artist at a conscious level. Intuitive thought is a skill that artists, in particular, have honed to a fine level. And yet, such approaches, building on non-conscious modes of human internal discourse, are as valid, if less understood, than scientific "logical" reasoning. It is partly because of this "thinking outside the logic box" that new insights can often be

found. In fact, noted author and academic George Lakoff maintains that our primary mode of thinking and solving problems is metaphorical, and that metaphors in fact, can trigger new concepts that reveal deeper realities[1]. Art is one means to bring metaphorical thought to the forefront of consciousness, and is why we focus on the intersection of science and art to increase understanding of data, via creative expression and data-driven experiences that serve to bring numerical measurement and evidence into human-centered focus.

Julieta: The way we articulate data has been traced back to our experience of space both in terms of navigation and handling of objects. Investigations of spatial perception that artists have been developing connect with the expansion of the senses through technological means that empower us to understand phenomena that lie beyond direct spatial and temporal realms. It makes sense that complex relationships among structures can be better internalized though direct immersive interaction supported by the dynamic structure of the body and its perceptual mechanisms.

Ruth: In working at the intersection of art+science+immersion, I have defined data-driven experiences as those where data, either from a data repository, or from people's interaction with systems themselves, drives the experience, which is primarily exploratory. This stands in contrast to hypothesis-driven experiences in which specific theories or questions are tested and which may both utilize existing data sets as well as generate new ones. The advent of massive and abstract data sets is changing our approach to fields as diverse as finance, medicine and astrophysics. My interest has been in the transformation of the life sciences, and in particular genomics, proteonics and metagenomics in which data mining of large data sets and associated metadata offers opportunities to explore new interactive modalities and representational schemas.

Laura: My experience is that scientific reasoning is not so linear and is in fact inspiration-driven as well – the difference is more that scientific reasoning has to be explained, not expressed, as in artistic thought. Serendipity does play a role in the sciences as well. One thing that is interesting to me about bringing art into science and vice versa is the chance it brings to mix experiences and possibly induce this kind of serendipity[2]. C. P. Snow discussed the growing cultural divergence between the traditional liberal arts and the sciences in terms of disadvantages[3], but there is an advantage in that because people in these two areas can have differing cultural experiences, this means that there is opportunity for people immersed in a given domain to hear things from a very different point of view, long after they have achieved expertise in their own field, that might give new insight.

Jacquelyn: For me the most important dimensions of data driven experiences is that of the human participating and immersing within the data of the experience, whether that data is numerical, subjective, behavorial or even face to face. Ultimately all data needs to be interpreted or assessed by a human element to be meaningful, and so for me data is only a starting point for the overarching human experience and the meaning derived there from.

Laura: This is interesting in that each individual has his or her own intellectual personality, and two people need not interpret the same data the same way (although they might).

Julieta: While each person involved in the creation of visualizations have intellectual personality (isn't that style?), a practitioner has an understanding of how his/her style affects the experience. In refining a visualization or simulation, the data is displayed as to enhance aspects of it. I am not sure what can be said meaningfully about differences that people may have in regards to perceiving the visualization because that is the same as with reality.

2.2 Defining Data-Driven Experiences

What are data-driven experiences? What is it that they are not? What can they be? These questions arise from the continuum of methodologies and products represented by our respective creative practices. We all share the belief that "data-driven" relates to the use of data about a phenomenon as the primary driver for an *experience*. Additional data, such as input with our bodies and gestures, is also data in the context of immersive systems. Position, gesture, selection, for example, are data elements reflexively generated through user interaction with immersive systems and can simultaneously drive the system in a self-reinforcing loop. A data-driven experience resides at the intersection of scientific data and the data retrieved from a human body as a perceptual system, and is where art and science encounter and communicate with each other in the context of the human agent. Data-driven experiences can encompass a spectrum from highly realistic simulation to abstract symbols to personified illustration. While the continuum from reality to simulation to aesthetic interpretation is based on state of art knowledge about something, the use of salient or "ideal" features drive the design of simulation experiences that exist at the art+science+immersion intersection we are advocating.

Jacquelyn: Bringing data into the domain of the human who must reckon with it, understand it and bring that understanding to bear on human needs, wants and desires, is what, for me, makes the gathering of that data worthwhile. Without the human in the loop, data is a meaningless collection of facts, figures, numbers, or bits. With the experiential aspect, it becomes resonant with our understanding of the greater world beyond us.

2.3 Perception versus Narrative

Pure perception (sensory input) emerged in our conversations as a counterpoint to narrative, useful to establish yet another axis or continuum within which to reflect upon the potentials of meaning for this intersection of art-science-immersion. Narrative is hardwired in us as humans and offers us an evolutionary advantage as our primary means of sense making. As Zlatev (2009) points out, language –and by extension development of narrative– are an evolutionary need for common consciousness with others, where language itself is our way of thinking together[4]. Perception is an individual phenomenon, but to reconcile that with people around us we need to elaborate our experiences into narratives, as ways of thinking and as a consensus building process. We also consider narrative as a post-processing activity relative to perception (sensory input) with potential to both illuminate and mislead.

The intersection of art-science-immersion-data brings highly abstracted data back into the realm of the sensory, with emphasis placed on developing visual and other modalities to allow products of thought to emerge into the perceptual world. So, where does narrative fit into data rich immersive experiences? And, can it? Can hypothesis generation be considered a narrative as much as "story" as a narrative? As immersive experiences gain ground for bringing products of thought into our perceptual world, might narrative actually impede us from seeing "what is there." This interplay is a point of caution in both science and cultural production, but can discussing it up front and knowing you have engaged the possibilities serve to immunize you from being mislead? This is of particular importance in simulations where technologies and representations that are extensions of our senses are increasingly coupled with real-time/interactive experiences of data. In the process of constructing meaning from virtual and augmented realities, when do you stop paying attention to reality? How do you determine which reality is more salient – the physical one or the virtual overlay? Or do they only become meaningful in tandem? In Husserl's thinking, the overlay of realities without presupposition can help us get to the essence of the thing. Does a narrative then serve to shield us from understanding that essence, or enhance it? In Phenomenological reduction (*epoché*) we are asked to suspend judgment and experience the thing itself without assuming what we already know[5]. Is it possible to create experiences that are so immediate, that they need no narrative? Or, can there exist a sweet spot or counterpoint between the immediacy of the data-driven experience and narrative?

Julieta: The framing of language as an evolutionary result of the need for collective consciousness is very interesting to me because of the process of abstraction that has moved it away from literal representation in order to negotiate collective thought. This may not be a central point to make here but data is an abstraction and here we are: trying to utilize it to enhance thought.

Laura: I approach narrative with caution, because it tends to induce a conclusion, and leads one to disregard conflicting data. Advertising, for example, is a master of short and effective narratives, but – they want to sell you something. Today's media can provide a narrative that is sometimes questionable. On the other hand, narrative seems to be almost hard-wired into the human brain, and really, scientists are trying to explain things: in other words, provide a narrative.

Julieta: I think the term narrative is a bit elusive in this context too. I also feel cautious about it because it negates the real time experience UNLESS… we redefine it as a structure created from the experience, or something like real time sense-making (see my comment on image schemas two paragraphs ago).

Laura: Some questions would be: who is telling the story? How was it generated? When was it generated, in terms of the data chronology? Was it tested, and how? Was there a motive, other than understanding (and does that even matter, if the story is correct)? It's worth pointing out that even a wrong story, or a badly motivated story, can have value, but not necessarily the value the teller of the story wants to present.

Julieta: Is this referring to an experience designed with a broader or narrower goal in mind? Technically speaking, a broader goal could accept a range of values but I think that the range should be clear to the artist. Otherwise, the artist cannot claim authorship, in my opinion, and the piece is just bad/wrong/unworthy of discussion (as art) other than as if the consequences of an accident.

Laura: This speaks to the data-driven/hypothesis-driven distinction Ruth drew earlier. A hypothesis is in some sense a suggested story, and it is tested to see if it will fit data. On the other hand, one can approach data in an exploratory way.

For example, one can keep an eye on anomalies. To see anomalies, one needs some kind of apprehension of the world (how are things usually and why is this different), but this world-view need not be a simple as a narrative to be useful, and could conceivably be as large and untellable as the world itself.

Ruth: I have attempted to design exploratory experiences that allow people to have as much flexibility as possible in developing their own interpretation (narrative) of a given data set or interactive system as possible. Yet, even with this goal in mind, the fact is that the choices of materials, systems, representational schema with which these systems are created are all a type of framing narrative in and of themselves. As a result, they are not devoid of content and are not truly open and objective systems. Therefore, I see narrative as inescapable in any human endeavor, and in art-science in particular, as playing a role at both ends of spectrum as well as a role in mediating and building a bridge between them.

Laura: I would argue for a dialectic approach to narrative/experience and closed/open and subjective/objective, so as not to be subsumed into either extreme.

Julieta: What would make a system truly open? How is this system "closed" or subjective? My understanding would be that by exposing the system's subjectivity, this problem should be solved… I am not sure there is a point in trying to formulate objective experiences because that could also imply ignoring the viewer.

Julieta: Perhaps we can claim an understanding of perception and its connection to sense making as central to the role of the artist. This would help articulate the notion of narrative that Ruth is formulating here.

2.4 Embodiment and immersion

We next turn to the concept of immersion, or inclusion of the body within the data–driven experience. Our primary question here is: Does the inclusion of the body in the interaction help understand data better? And if so, how does this better understanding come about? The importance of the body as a shaper and mediator of our thought processes is widely accepted as the basis of the embodied mind thesis by experts in a wide range of disciplines, from philosophy[6, 7, 8] to cognitive science[9, 10, 11, 12] to neuroscience[13, 14]. At the intersection of art and science with big data, we can look to how artists, in particular, excel at making abstract ideas experiential, and how they engage the human within immersive experiences that encompass and use the whole body. We believe that the inclusion of that human body within the data can contribute to a fuller understanding of the data and its relevance to the human condition.

Given that immersive systems are often designed to relate to the entire body, we also consider whether there is a continuum between perception and embodiment, or if they are one and the same. Many forms of scientific inquiry can be considered as less embodied than others. Mathematics and computer science are closer to pure thought than observational or empirical field work. In the arts, the process of making 2D and 3D forms or interactive installations provides a physical empiricism whereas theory or philosophical considerations tend to align with dis-embodiment.

Julieta: Theories of embodied cognition focus on mental processes rooted in bodily interactions with the world, and examine how the body – with its sensorimotor processes – shapes the human mind[15]. Immersion is designed around the body, not just acknowledging vision, but integrating locomotion and gesture as well as other sensory content to the experience, which may be relevant to the data being presented. Designing for embodiment may also take into account as many perceptual clues as relevant, fragmenting complexity and matching it to the complexity of the body to better take advantage of human perception.

Laura: One interesting thing about working with multiple senses in an immersive setting is that they seem to be more than additive. For example, if the immersion includes both visual and auditory input, the experience is not just the visual and also the auditory, but is both and also something greater than the two. The inclusion of the body in the experience permits use of proprioception in the mix.

Jacquelyn: I agree with Laura, in that we should utilize more human perceptual systems. Some senses, such as smell, go directly to our limbic system and open up new emotional avenues for understanding data in an experiential form.

Ruth: I am attracted to immersive systems for their ability to expand the interactive repertoire to include full-bodied engagement or a more "natural" interface to very large and abstract data, bringing these in to relation with the body in ways that enable us to apprehend what is essentially invisible yet vast, in ways that give us a sense of scale and scope. I have utilized these types of systems more for poetic purposes as well as understanding. As the process of designing towards a poetic and aesthetic meaning develops, it often leads to the emergence of patterns that could, if developed further, become part of a new understanding or system of meaning. In this way, interactive and dynamic immersive experiences that are data driven become a type of palimpsest – an ever re-writable narrative exploration of a data space.

Julieta: I agree with Ruth that by creating embodied and immersive interactions with data we are ultimately measuring the data against human scale and the scope of human perception, because data has to be remapped/tailored to our senses to allow us to examine "anomalies" as Laura puts it. This is most striking in cases of data that enable users to experience what is radically outside of the realm of human perception like large-scale visualizations.

2.5 Big Data and data driven experiences

Big data is emerging as both a challenge and driver of innovation and discovery in all areas of human endeavor. As such, big data is a major dimension in all of our work and fuels a significant portion of both applications and research in the development of immersive experiences. We will explore several topics related to big data and immersion. These include the relationship of scope and scale of data to immersive experiences, how the data evolves (its production via sensors and measurements versus simulations, its processing and resolution) with computer or sensor capabilities, and how data of ever-increasing scope can be represented in ways that lead to insight. Can immersion and or human-in-the loop interactive systems help with exploration and eventual understanding? Or is there a fundamental question that remains: how does one fundamentally make data immersive? What is it that makes data immersive? is data more readily transformed to knowledge within an immersive experience? While not a concept at the same level as perception, big data as a concept opens new territories and requires us to reflect on the possibilities for crowdsourcing as necessary for reasoning or even sensing applications that compute resources can not accomplish.

Immersive systems have real-time constraints. For truly massive data this limitation imposes constraints on being able to query data on-the-fly. This results in a secondary level of interpretation in which a layer of narrative that is added to the data as one selects which data to render, which to eliminate, and at what resolution to generate a render, which is distinct from the underlying raw data representing a particular phenomena. Given our experience in which every improvement in computational resources results in larger and larger data sets, in the case of the largest data and most compute-intensive applications, immersive and interactive systems out pace the underlying data as it is not available to be queried in real time. For each new set of questions, the raw data needs to be selected, computation re-run, and renders generated. This the need to find new approaches for working with big-data and immersive systems a living issue.

Laura: This is a major question at Los Alamos. The data is big enough so that one cannot work with it truly immersively. It just takes too long to read from disk to the analysis machine. The lack of temporal continuity disrupts the workflow and interrupts the immersive experience. This is not going to improve, either, since the data is getting bigger and bigger. One can, of course, make a movie, or pre-generate some geometry to explore, and these do provide temporal continuity, but do assume a narrative.

Julieta: It makes sense that data visualization does not end up in a given representation, but data driven experiences allow for reconfiguration of the experience within specific parameters where anomalies or salient features can be found and further explored. Through immersive interaction, the user is not just placed inside the data to navigate different viewing angles, but can activate or trigger aspects of the data through embodied interaction. Since data can be experienced at varied resolutions to probe patterns that may emerge, be maintained or change, more detailed data can affect all the different discrete scales that configure the immersive data driven experience. Resolution can also change depending on the scale being experienced.

Ruth: My fascination with vast and abstract data sets is both their completeness and incompleteness. While we can digitally sample natural phenomena, we cannot reconstitute them from these samples, even in the most realistic of simulations and virtual or augmented environments. To sample anything digitally we must choose what to sample, at what resolution, what file format to store the data and so on. To manage this complexity, we make choices during data capture, processing, storage, analysis and interpretation. Each of these choices is yet again an example of framing narratives are created as part of the process. They also represent ways of stepping down the complexity and wrangling "big data" so that we can work with it as if it were "small data." Artists have evolved practices for evoking deep and resonant experiences from complex and often unpredictable input. I believe this is the strength of art-science and it's ability to engage big data meaningfully: evocative experiences that overcome the limitations of our ability to manage the complexity of big data.

Laura: In some sense, the world itself is the biggest of big data, and yet here we are, having navigated it successfully yet one more day. How much fidelity to the data is needed for the outcome to be useful?

Jacquelyn: It boils down to the human interpretation (and need for that interpretation) of the data we are immersed in. What about our human evolutionary stance can be leveraged to help us navigate data in terms that are most useful for our continued interactions with the world and even how we evolve as technologically symbiotic organisms?

Julieta and Laura: In tackling technical constraints we may evoke the human perceptual system.

Julieta: It seems like data per se, massive and scary has to be tackled despite its technological and perceptual constraints. Dynamic resampling of data, interaction with the data itself in the process of experiencing it is part of immersion. Whether data needs to be "massaged" or "sampled" to help narrow down areas where relevant issues may be found, the resulting immersive representation clings to our eagerness to make sense of it.

3. REFLECTIONS

Scientific reasoning may not be linear and may in many aspects be inspiration-driven. At the intersection of art and science with big data, we can look to how artists, in particular, might excel at making abstract ideas experiential. Ultimately all data collected or generated for scientific research needs to be interpreted and assessed by a human to be scientifically meaningful. Without the human in the loop, data is a meaningless collection of facts, figures, numbers, or bits.

Narrative seems to be almost hard-wired into the human brain, and really, scientists are trying to explain things utilizing big data: in other words, provide a narrative. We see narrative as inescapable in any human endeavor. On the other hand, premature narrative can be restricting, and one of the benefits of having and exploring large amounts of data as we have discussed is the opportunity to explore other narratives, or even explore without a preconceived narrative.

Mathematics and computer science are closer to pure thought than observational or empirical field work. In the arts, the process of making 2D and 3D forms or interactive installations provides a physical empiricism. As the process of designing towards a poetic and aesthetic meaning develops, it often leads to the emergence of patterns that could, if developed further, become part of a new understanding or system of meaning.

Immersive systems have real-time constraints. For truly massive data this limitation imposes constraints on being able to query data on-the-fly. Creating embodied and immersive interactions with data we are ultimately measuring the data against human scale and the scope of human perception.

We see many possibilities for new explorations using the methods of art, science and technology together, such as:

- The internalizing of complex dynamics though direct immersive interaction supported by the dynamic structure of the body and its perceptual mechanisms.
- The tailoring of technologies to the human body to better connect data to human perception and cognitive processes.
- The exploration of existing narratives, and the generation of new narratives through free explorations of data.

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