New Media Affordances & the Mathematical Sublime

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ABSTRACT

Technological affordances of the digital era have transformed the manner in which we interact, approach, and comprehend mathematical expressions that otherwise extend beyond our cognitive ability. New media visualizations of the late 20th/early 21st century have employed a variety of mapping techniques to explore the perceptual, aesthetic accessibility of these expressions in manners heretofore unprecedented.

The research outcomes of this paper are intended to support the development of a native mobile application utilizing augmented reality space to create an immersive model of the solar system. The project's subject matter provides an opportunity to address the design challenges posed by extremely large numerical scales and representation of highly dynamic proportional relationships. As such, I intend to explore the affordances of augmented reality within this sphere and assess the potential benefits of its use. The eventual deliverable is wholly intended to provide its audience with uniquely accurate level of comprehension of the relationship between the various planets the solar system, their relative size, and respective heliocentric distances. Further, the project aims to achieve a degree of *cognitive stickiness* that will allow users to retain this understanding over time.

Commonly, numerical values expressed in orders of magnitude are difficult to comprehend, particularly so for audiences that are less-mathematically inclined. The deliverable of this project is intended to narrow this gap in comprehension in order to create meaning and make interpretable a true model of the solar system to a general audience.

Owing to early visual representations of the the sublime in 19th century romanticism, the project name, in homage to Russian Armenian painter Ivan Aivazovsky, is dubbed, *Wave 9*.

1. INTRODUCTION

My research will provide philosophical and cultural/historical contexts for the characterization, depiction, and representation of the sublime, the incomprehensibly expansive, or otherwise unrepresentational. This context will set the stage for exploration of these themes in the digital era and the possible corresponding cultural, social, and educational values that may be derived. Lastly I will explore the affordances of augmented reality and physical space as a means of 'narrowing' the cognitive gap.

1.1 Through the Lens of Kantian Aesthetics

While the crux of my exploration in the areas of extreme numerosity and magnitude perception is affixed to design oriented elements of representation and visual conveyance of values of vast scale, I will first look to set the stage by considering philosophical contributions of the 18th century philosopher, Immanuel Kant. So, while I ultimately do not intend to make a philosophical argument, I would like to use the lens of Kantian aesthetics to draw a distinction between realities that are merely known to be true versus realities that are understood within the frame of our aesthetic intuition. In order to consider this fully, we must first consider the nature of the perceptual limits of human cognition as they are derived from environmental factors contributing to species survival.

One of the great revelations of Darwinian theory is the efficiency with which species evolve. There is very little room for extraneous capability, skill, or cognitive ability. Plainly, what survives is what contributes to survival, these are the traits that are passed down through the evolutionary trajectory. In this context it becomes apparent that understanding the world as an expression of quantum entanglements is of comparatively little value when weighed against the ability to estimate the closing speed of an adult cheetah. It then comes as no surprise that the underlying nature of reality would occur to us as outside the realm of intuitive inference. The same therefore could be said to extend to scaled values and numerosities that extend beyond the scopes of anthropic measure. Humans live at human scale, and our comprehension of environment is best expressed quantifiably within the terms that best support our evolution and survival.

In a 2016 interview of physicist Max Tegmark, interviewer/neuroscientist Sam Harris outlined the basic issues of these cognitive limitations. In the context of my research the following terms are a useful frame to help understand the nature of cognitive human limitations:

> *One thing we can be sure of is that our cognitive capacities, and our common sense, and our intuitions about reality have not evolved to equip us to understand reality at the smallest possible scale or at the largest... We have intuitions that are tuned for things at human scale, for things that are moving relatively slowly, and we have to decide whether we can mate with them, or whether we can eat them, or whether they can eat us. It is no surprise therefore that the deliverances of science … are deeply counter intuitive.*[1]

The character of reason however, is an innate intuition of mankind that can, has, and does serve us quite well in realms beyond our aesthetic comprehension. With it, we make assertions about phenomena that are carried out on scales well surpassing our innate cognitive abilities. It is with reason that we understand the orbit of the earth, predict weather patterns, and map the genome. While these subjects may not be experienced directly, their assertions may be tested, can then be demonstrated empirically through phenomenological effect, and made measurable within anthropic scales (*id est* that which we can see, touch, or otherwise experience). Physicist Max Tegmark, as interviewee of Mr. Harris explains how that which is deeply counterintuitive may be understood to be true through empirical assessment:

> *Some people tell me that theories that physicists discuss at conferences from blackholes to parallel universes sound even crazier than a lot of myths from old time about [fire-breathing] dragons, so shouldn't we dismiss these physics just like we dismiss these myths. To me there is a huge difference here in that these physics theories, even though they sound crazy, actually make predictions, that we can actually test... If you take the theory of quantum mechanics seriously for example and assume that particles can be in several places at once then you predict that you should be able to build this thing*

[1] Harris, Sam. "Waking Up." Audio blog post. The Multiverse and you (& you & you). Sam Harris, 23 Sep. 2015. Web. 30 Mar 2017.

called a transistor, which you can combine in vast numbers and build this thing called a cell phone, ...and it actually works! [2]

While confirming logical assertions about sub-intuitive realities through empirical testing is valid ground for a truth-claim about an underlying reality, it does little to help us grasp the nature of this reality on any intuitive level. This is so, despite that fact that these predictions express a reality about the very world in which we live, the world that occupies us, claims us as under its domain. It is this line that Kantian aesthetic philosophy so succinctly distinguishes.

The extent to which the human mind can grasp the enormity of our universe and the spaces within it (an effort doomed to inevitable shortcoming) is understood in Kantian philosophy as the *aesthetic sublime*. Opposing, the *mathematical sublime* constitutes the aspects of the universe that extend beyond our cognitive ability. While we may not understand these aspects of the universe, we understand them to be true through logical inference, deduction, and the application of reason. It is this power to derive superhuman truth-claims extending from logical inference that led Kant to hold reason up as among humankind's greatest virtues, as it allows us to *know* the world in ways that could never be understood aesthetically.

Because this difference between knowledge and understanding is so efficiently distinguished in Kantian aesthetics, I will refer to these terms recurringly throughout this essay. The 'aesthetic sublime' is used here in reference to our intuitive understanding of reality, that which we experience as falling within the comprehensible range of human understanding, and anthropic scale. The 'mathematical sublime' is used in reference to our experience of values beyond our innate intuitive comprehension, that which exhausts or otherwise stretches the usefulness of anthropic measure.

There is one additional area of numerical perception into which I intend to delve, in at least a cursory manner: numerosity. My use of this term will typically refer to numerical values of such size that it is beyond human ability to interpret reliably. Some examples where my exploration may come into play could include: the number of birds in a flock, peaches on a peach tree, stones along a shoreline, or jellybeans in a mason jar. These values and numerical representations are examples of terrestrial experiences for which our innate cognitive abilities fail to register with any degree of accuracy. They are in my view the middle ground in which our understanding of vast numerical values begins to disintegrate. Nonetheless, I intend to explore how numerosity perception, while overwhelming to our visual sensory might be leveraged to effectively reveal the underlying nature of a given subject matter in a way that is more comprehensible, accessible.

1.2 Visual Representations of the Sublime in Romantic Art

Not coincidentally, following the death of Immanuel Kant, we saw the subsequent rise of romantic art. In it, the sublime emerged as a core theme of this artistic movement. Its presence in 19th century landscape art is pervasive and rich. These representations illustrate much of the core concepts of the Kantian aesthetic sublime, as they trace our awareness of realms beyond comprehension, but depict them as inexpressibly immense, beyond reach. Commonly they depict some intervening aspect of nature that prohibits their accessibility.

Take for example the painting 'The Ninth Wave' by Russian Armenia painter Ivan Aivazovsky. In its depiction of the sublime we see a dim horizon, low and tearing through a cloud scape. The position of the sun in the sky, a concentrated, profusion of light signifies the fleeting nature of our exposures to the immensity and grandeur of sublimity itself. In the foreground we see a cluster of men, dwarfed and desperate, clinging to the broken, shattered mast of a great ship. The girth of the ship's mast suggests a ship of great size, an achievement of human engineering and cognitive capability. Despite its grandeur, the wreckage is symbolic of the relative insignificance of human achievement against the backdrop of the unattainable sublime, the immensity and

[2] Harris, Sam. "Waking Up." Audio blog post. The Multiverse and you (& you & you). Sam Harris, 23 Sep. 2015. Web. 30 Mar 2017.

dominance of the natural spectacle. Further the cause of this wreckage, the persistent onslaught of massive waves, is symbolic of nature's prohibitions of cognitive accessibility. The limits of our nature permit only merger approach, a distant view, from which further approach is aggressively ceased, halted by a violent and unforgiving intermediary nature, an ocean of virulent and suppressive force.

Alternately we might consider another example, such as the painting 'The Sea of Ice' by German painter, Caspar David Friedrich, which in uplifting parlance is sometimes referred to as 'The Wreck of Hope'. Similar to the visual language of 'The Ninth Wave,' 'The Sea of Ice' utilizes much of the same iconographic and representational elements. Both paintings feature the lost wreckage of a large ship, echoing the theme of nature's prohibitive exclusions.

Like 'The Ninth Wave', 'The Sea of Ice' also centers around a majestic skyscape, simultaneously distant and alluring, seductive, yet inaccessible. Whereas 'The Ninth Wave' separates the viewer from the vast openness of sky with violent oceanic storms, "The Sea of Ice" instead interposes a cold, salty void of arctic ocean. In this sense, 'The Sea of Ice' suggests not violent exclusion, but cold indifference. Use of this subject matter implies that the environment, the natural world beyond our cognitive reach is not threatened by human presence, but merely indifferent to it, unfeeling, and without affect. It represents at its core an inhuman, unfeeling, barrenness. All its signs indicate its unsuitability for human experience, and yet the glimpse of vast glowering 'other' world winding through the cloud cover, inspires a grieved, uncanny gravity, a desperate longing for its unattainable whole.

Data visualization artist, Lisa Jevbratt, in her examinations of the role of the sublime in data visualization describes the painting thusly.

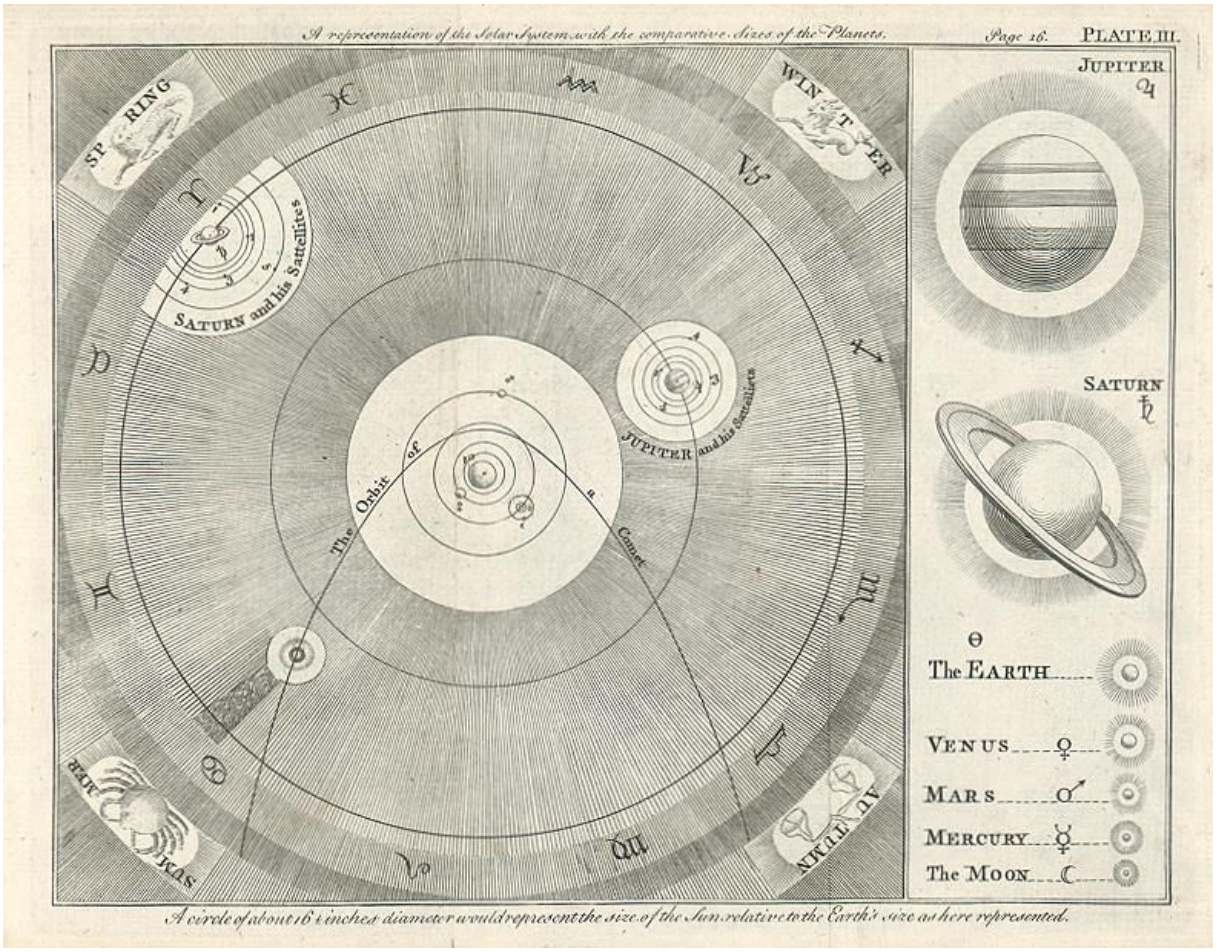
> *In Caspar David Friedrch's "The Polar Sea" [aka 'The Sea of Ice'] we look out on an endless inhospitable ocean of ice, and a shipwreck - a trace of an attempt to do the impossible, to go 'there', to reach for and understand the unbearable void.*

We look up at the starry sky and we sense a fear of not comprehending and being engulfed, a fear of the unknown, and simultaneously we experience a longing for the inaccessible, impenetrable darkness. [3]

Jevbratt, in her response to Friedrich's painting captures both the allure of understanding, and the natural limitations of our cognitive abilities. In tracing the perimeter contours of her 'impenetrable darkness', she illustrates a distinction between that which may be understood to be true, but cannot be understood, the aesthetic versus the mathematical.

Such imagery is widely pervasive through the romantic movement. In part, the early part of the twentieth century, our experiential relationship to the mathematical sublime was informed by the available means through which we had to interact with it. Given computational constraints and limitations to interactivity afforded by19th and early 20th century representational tools, representations of the sublime in an aesthetic context commonly demurred exclusively to the symbolic, purely artistic. More scientific renderings of the mathematical, however, such as those pursued in scientific illustrations of the solar system, tended toward illustration of a single property of the solar system's composition, failing to incorporate broader contexts of scale and dimension.

Considering the scientific perspective and the challenge of representation of the dynamic scale of objects within the solar system, let's take for example an illustrative visualization from as far back as the 16th century. The below image designed by an unknown engraver was published in *A New Geographical and Historical Grammar* in 1772[4].



[3] Jevbratt, Lisa, "The Prospect of the Sublime in Data Visualizations", YLEM Journal; Large Data Sets and the Sublime, number 8 volume 24 - July/August 2004

[4] Salmon, Thomas, "A new geographical and historical grammar" 1772, London, W. Johnston

The layout of the illustration is separated into two distinct categories of visualization: distance, represented with the left panel, and size, represented in the right panel. The illustrator attempts to resolve the representational challenge of the solar system's dynamic scale by segmenting the representations by subject area of focus. This strategy presents information to the viewer by unidimensionally compressing the representation. As a result, the representational size of the planets is wildly skewed in the left hand panel, while distance is effectively disregarded in the representation of the planets on the right panel.

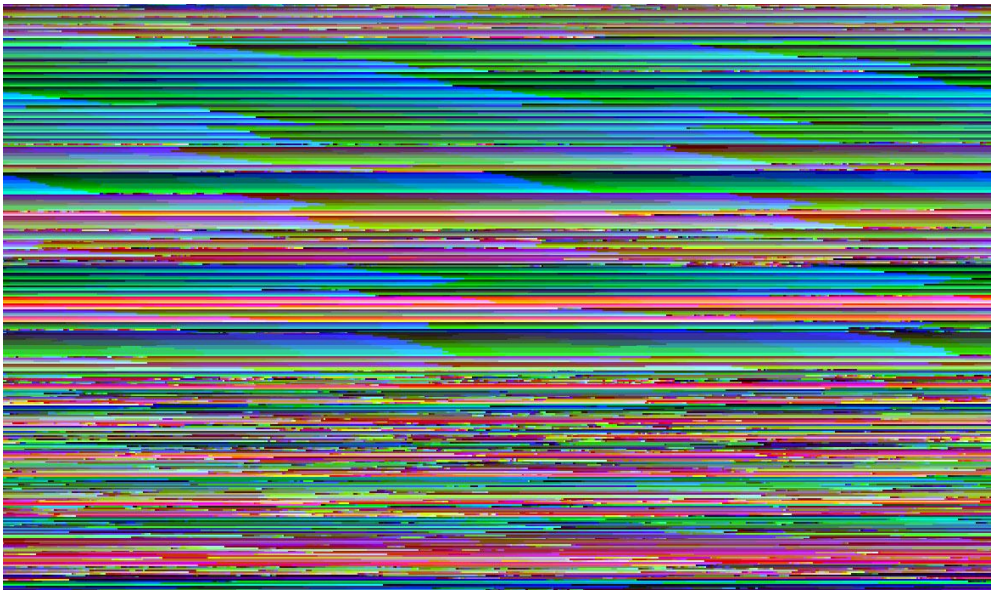
While this method of representation is effective at communicating the comparative size of the various planets and their respective distances from the sun, it does little to empower its viewer with a holistic understanding of the solar system at scale. That is to say that it does little to impart in the mind of its viewer any information about the actual size of the solar system itself.For this reason I put forth that a design solution looking to narrow the gap in understanding can only be effective if it alleviates the problem of unidimensional compression, by truly representing the solar system at scale. Only then will a visualization tool approach conveyance of enormity in a meaningful, comprehensible way that is aligned with underlying impulses of romanticism and representation of the sublime.

2. TREATMENT

At the millennial turn, the robust processing and computational power of new media technologies breathed new life into the relationship between what is representationally and experientially possible. Large datasets not only can be collected and aggregated in new, more powerful ways, but so too have the means of interaction with large volumes of data whose very existence is only newly possible. In this section of my research I intend to explore the transformation of these relationships, and survey various representational strategies of approach taken by some data visualization projects.

2.1 The Anti-Sublime and the Shape of Numerosity

Much of the power of data visualization is drawn from the ability that technology provides to transpose what in Kantian philosophy might be considered the mathematical sublime, into visual forms, representations and renderings that reframe what is otherwise impenetrable and uninterpretable into an aesthetic field through which audiences may again come to comprehend, make inference, and know.

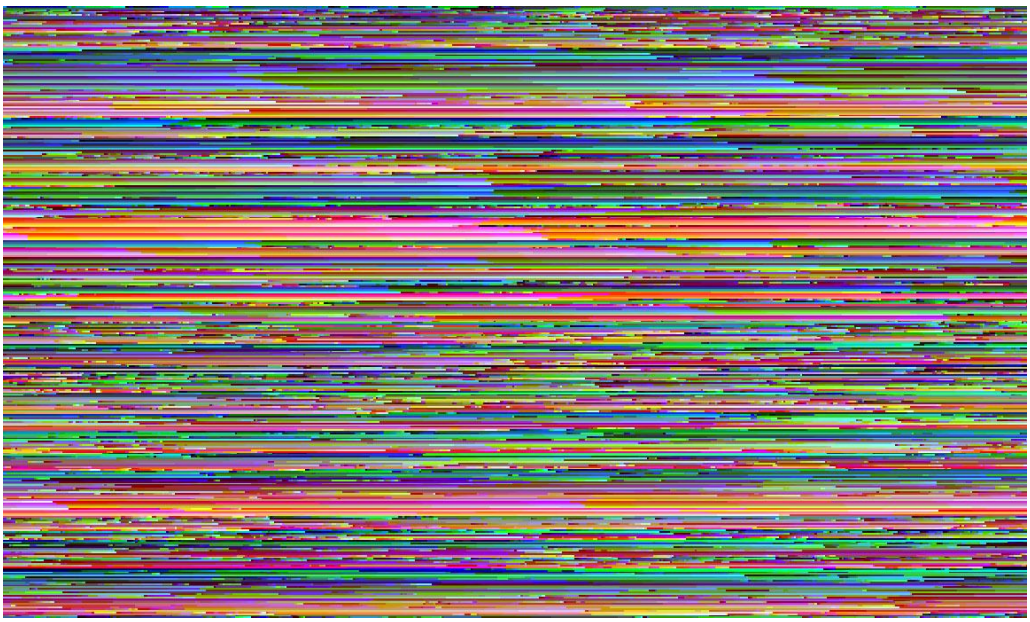


In an effort to consider the implications of this transposition of the mathematical sublime to an aesthetic space, I want to examine some assertions put forth by new media theorist Lev Manovich. In his essay 'The Anti-Sublime in Data Art,' Manovich examines how our relationship with a mathematical sublime is reframed by the advent of computational information processing and visualization.

> *With computers we can visualize much larger data sets; to create visualizations which are dynamic (i.e. to feed in real time data; to base graphical representations of data in its mathematical analysis using*

variety of methods from classical statistics to data mining; to map one type of representation into another.

Since Descartes introduced the system for quantifying space in the seventeenth century, graphical representations of functions has been the cornerstone of modern mathematics. In the last few decades, the use of computers for visualization enabled development of a number of new scientific paradigms such as chaos and complexity theories, and artificial life.[5]



With the variety of examples Manovich provides, he demonstrates how the visualized reframing of datasets of incomprehensible complexity, may be understood through graphical rendering, and reframe the interactive experience we have of the physical, natural world.

Curiously, the development, adoption, and use of these visualization and analysis tools also feeds into, and generates, a rich ecosystem of data and information, making possible meta level, self reflective analysis, a tool that requires use of itself, use of its own mechanisms in order to be understood. For example, the internet and its informational datasphere becomes itself a subject, its own true nature being one of unknowable complexity. One powerful example where the tools of visualizations and programmatic processing of information might self-illustrate in a way that more broadly makes accessible the technological ecosystem of the internet into the aesthetic field is the work of aforementioned Lisa Jevbratt.

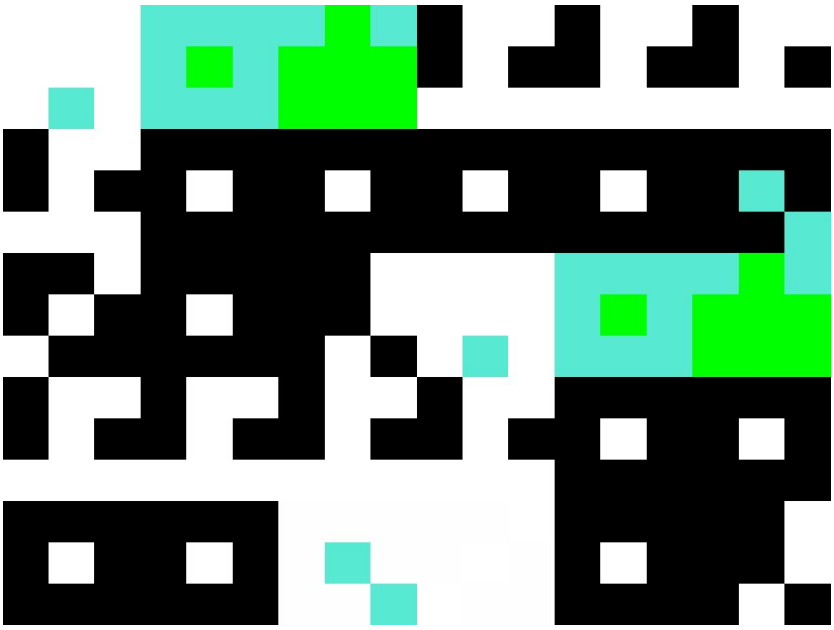
In an earlier day of the internet, just prior to the turn of the millennium, Jevbratt embarked on numerous projects premised by the design of a web crawler that systematically checked IP addresses to determine if a site existed at that location. Where sites existed, they were logged in a database and various site attributes compiled. One unique aspect of these projects, is that sites were logged in the database regardless whether or not the sites were made publically available.[6] What emerged from this effort was a picture of the internet as it is otherwise unknowable. The hidden dimensions of its network brought to the surface.[7]

In the earliest incarnation of this series Jevbratt sought to capture the internet in its entirety (each and every IP in existence) in her project 1:1. In 1:1, Jevbratt revealed a view of the internet unlike any anyone had seen before, unlike any that had yet been articulated. Here, Jevbratt describers her project as a new revelation, a discovery of place, of an amorphous body with narrow bones coming into view:

When navigating the web through the database, one experiences a very different web than when navigating it with the "road maps" provided by search engines and portals. Instead of advertisements, pornography, and pictures of people's pets, this web is an abundance of non-accessible information, undeveloped sites, and cryptic messages intended for someone else...The interfaces are not maps of

[5] Lev Manovich, "Data Visualization as New Abstraction and Anti-Sublime" (2002) accessed March 15, 2017, http://manovich.net/content/04-projects/040-data-visualisation-as-new-abstraction-and-anti-sublime/37_article_2002.pdf
[6] Lisa Jevbratt, Introduction to 1:1, http://www.medienkunstnetz.de/works/1-1/images/2/
[7] **Lisa Jevbratt, «1:1», 1999 – 2001** Every IP 1999 | © Lisa Jevbratt

the web but are, in some sense, the web. They are super-realistic and yet function in ways images could not function in any other environment or time. They are a new kind of image of the web and they are a new kind of image.[8]



Here, Jevbratt arrives at one of the most compelling aspects of her work and reveals new insight into the true nature of the internet and our experience of it. While this work is of an earlier age of the internet, what Jevbratt points to about the use of search engines is of a renewed and seemingly perpetual truth. The functional efficiency of search engine results, while they make the internet more easily navigated, also serve to obscure the underlying reality of what the internet really is. To resample an earlier term, search engines present us with a version of the internet that is *unidimensionally compressed*. We enter a search term and what is returned is a limited representation of that term's presence on the internet. Search engine results deliver an artificially honed list of navigational options, and obscure the hidden depths of navigational options actually available.

While Jevbratt's output from this effort overwhelms the senses, and yields an image of the internet that visually inundates the viewer's eye with a barrage of representational color and shape, defying comprehension, it aims to illustrate a different truth, a truth of vastness, reach, and uncompressed complexity. [9]
Jevbratt's project, as you might suspect would prove unsustainable with time. In just two years from 1999-2001, the uptick in IPs began to skyrocket beyond the ability of her database to keep up with the explosive surge of the internet. What remains at this point are these early images of the internet emerging from its infancy. They now serve as a sort of photo-still, snapshots a previous era, of faces far less mature, less riddled, and depicting a still-somewhat numerable internet.

As the new century moved along, Jevbratt, in a related project, "mapping the web infome," wrote additional software that crawled the web, also collecting information and attributes about the various IP addresses it examined. In this effort, like 1:1, Jevbratt employs a brute force approach: collecting attributes en masse and compiling them into visualizations that reveal some underlying character of the web that is largely inaccessible in daily use.[10]

Her assertions about the driving forces of this work are described thusly:

> *The Web, the part of the Internet using the HTTP protocol, might not be an organism with a future. There may be other protocols or combinations of protocols yielding more fruitful environments. If so, this is the time to map the Web's chromosomes, to find its polymorphisms (the snips - small*

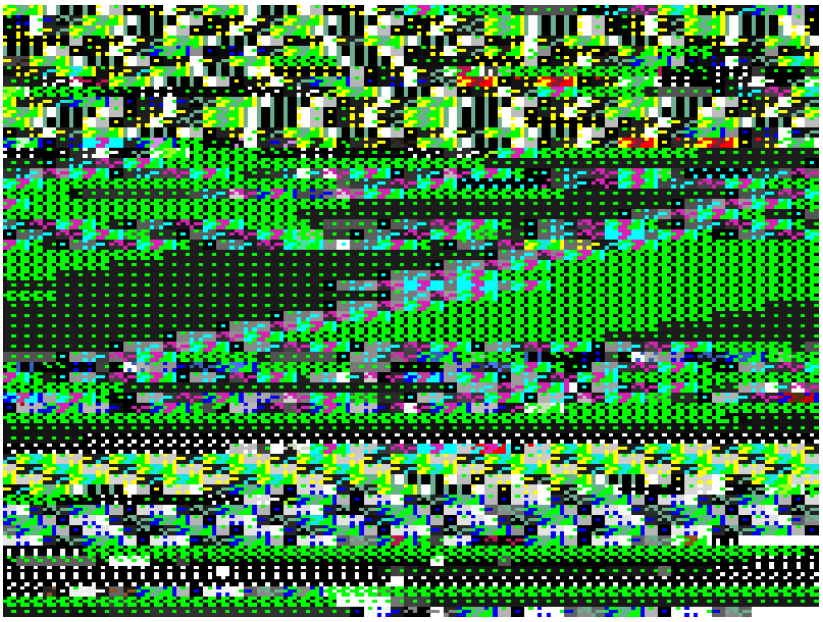
[8] www.c5corp.com/1to1

[9] **Lisa Jevbratt, «1:1», 1999 - 2001 Every** IP 2001 | © Lisa Jevbratt

[10] Lisa Jevbratt; Crawler: ID3088, Manifestation: #1. The crawler started on webpage: http://www.infonu.nl Pages visited:2 The crawler was set to visit pages more than once.

discrepancies in the code that tell us about its history), detect its 'junk data', and maybe in the process, discover and invent the grand infome behind it.[11]

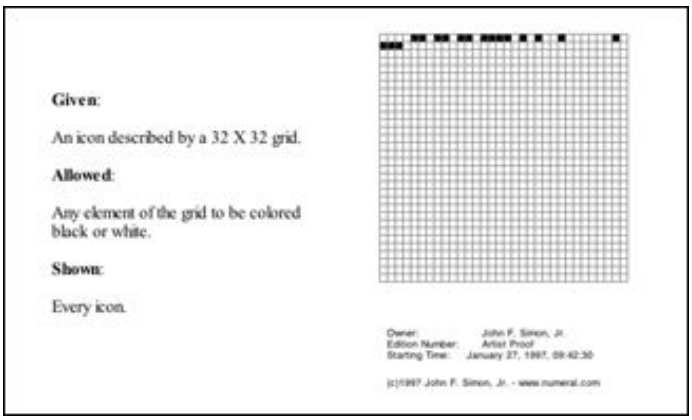
The project itself democratized the ‘mapping of its chromosomes’ through public invitation to create and initiate the software so that users may create their own crawlers and contribute outcomes to a catalog of visualized renderings of the internet. Each crawler initiated is designated a point of entry. As it crawls through the internet, the software compiles attribute details including the top-level domains associated with each IP, status codes, hyperlink style attributes, IP range, and number of hyperlinks connecting the page to other IPs throughout the internet. What is ultimately expressed is a view of the internet's underlying chaos, the furious duck feet paddling beneath the serene surface.



Furthering her introductions of democracy in her effort, Jevbratt made each submission subject to review, evaluation, and ranking in terms of the visual interest of the crawlers output. By democratizing the tool and its process, Jevbratt further enhances the degree to which her audiences engage with the information, here engaging in deep levels of complex information in a startlingly direct, unfiltered manner.

By this time, the internet had become too large, too complex, too deep to attempt anything similar to the efforts she made in 1:1. Whereas brute-force rendering of its numerosity of information had become prohibitively vast, Jevbratt elected to employ a more common approach to numerosity visualization: foregoing the illustration of totality in favor of underlying complexity. [12] Avoiding the disruptive nature of unidimensional compression, the work reveals to its viewer only a slice of the overall field. Rather than attempt to represent the whole through artificial compression, this technique illustrates the whole by extracting only a small frame.

Another project dealing directly with numerosity of vast scale from before the turn of the century is John Simon’s work *Every Icon (1998)*. In it Simon uses a similar technique: narrowing the visualized frame through which his audience will make inference about the totality of the dataset. The project takes a 32 x 32 binary matrix and renders sequentially every possible permutation of display. The process is executed with custom software built for this explicit function. Once it begins, the program runs, and runs, and runs, rendering second by second, moment by moment new and evolving visual arrangements of these binary squares. To date the program has been running since 1997 and continues to work through the first couple of rows of thirty-two.



[11] Lisa Jevbratt, curatorial statement Mapping the web infome http://128.111.69.4/~jevbratt/lifelike/curatorial_statement.html

[12] *Lisa Jevbratt; Crawler: ID3397, Manifestation: #0. The crawler started on webpage: http://project.carrot2.org/ Pages visited:201 The crawler was set to visit pages more than once.*

The visual experience of this visualization does not provide its viewer with any explicit understanding of the numerical value of its permutations, but instead transposes that vastness on a new scale. As Manovich describes, “Simon pursues a unique strategy of his own: he uses artificial life, cellular automata, and other computational techniques to create complex and nuanced images.”[13] With this technique, Simon’s work becomes less about the discrete visual renderings of possible icons, and more about the time it takes to render them. When a viewer experiences Every Icon, they can see the blips and flashes of each arrangement fleetingly flashing in their retina, mostly unable to digest, or appreciate the visual uniqueness of each. The visual sensory is thereby overwhelmed and the element of time steps into the forefront of the experience. Not only is the render progressing at a furious pace, but it has been doing so for decades.

It is at this point that these representations assume a particular character. The examples explored in this space largely push work into a realm of artistic expression, and so what usefulness may be retained if any? In what manner are we ultimately engaged and asked to reframe our understanding of our world. Manovich explores this concept:

> *I often find myself moved by these projects emotionally. Why? Is it because they carry the promise of rendering the phenomena that are beyond the scale of human senses into something that is within reach, something visible and tangible? This promise makes data mapping into the exact opposite of the Romantic art concerned with the sublime. In contrast, data visualization art is concerned with the anti-sublime. If Romantic artists thought of certain phenomena and effects as un-representable, as something which goes beyond the limits of human senses and reason, data visualization artists aim at precisely the opposite: to map such phenomena into representation whose scale is comparable to the scales of human perception and cognition.*[14]

There is contention, however. While these projects may arrive at a state of visual articulation and form, they may yet fail to speak a fully comprehensible language. Manovich’s claim that “these projects map such phenomena into representations whose scale is comparable to the scale of human perception” is dubious. Warren Sack, a critic of Manovich’s anti-sublime argument and positioning of this work, gives voice to a base criticism which should be considered. Here, in reference Simon’s Every Icon, he poses:

> *Simon’s piece enumerates every possible icon of a huge series by systematically filling in a grid of 32 by 32 squares, each of which can be black or white...Since there are 256 squares in the grid and since each square can be ‘on’ or ‘off’ there are 2^{256} possible icons. ...In other words, to see literally every icon, a visitor to the gallery would have to camp out in front of the piece for billions or years...This does not reduce the (almost) infinite to the easily appreciable finite: it is, I argue, an attempt at the aesthetic of the sublime, not the anti-sublime.*[15]

Both Manovich and Sack may yet miss at least some of the point however. There positions seem to presuppose an explicit utilitarian posture: that the value of a visualization might be measured primarily by whether or not it increases the speed, accuracy or efficiency by which a task is executed (as might be the case in science or engineering)[16]. This definition, while perhaps a popular or common convention for data visualization valuation, is an obvious mismatch in this context. It is important to note that the examples Manovich points to focus primarily on the sensory experience of the visualizations and therefore should be

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[13] Lev Manovich, “Data Visualization as New Abstraction and Anti-Sublime” (2002) accessed March 15, 2017, http://manovich.net/content/04-projects/040-data-visualisation-as-new-abstraction-and-anti-sublime/37_article_2002.pdf

[14] Lev Manovich, “Data Visualization as New Abstraction and Anti-Sublime” (2002) accessed March 15, 2017, http://manovich.net/content/04-projects/040-data-visualisation-as-new-abstraction-and-anti-sublime/37_article_2002.pdf

[15] Warren Sack, Aesthetics of Information Visualiation, September 9, 2009, accessed March 11, 2017, http://virus.meetopia.net/pdf-ps_db/WSack_esthetics-of-informations.pdf

[16] Stewart Card, Jock Mackinlay, Ben Schneiderman, Readings in Information Visualization: Using Vision to Think (San Francisco, CA: Morgan Kaufman Publishers

valuated based on the context in which the work functions and how effectively the value offerings specific to its structure may be yielded.

I put forth here that an element of usefulness is retained in this work. Emerging is an otherwise unarticulated voice offered as contribution to the dialogue, an illumination of an aspect of the relationship between participater and environment. This work precipitates a point at which the viewer is able to inject themselves into the experience, and come face to face with numerosity representations of enormous range. As in the case of Simon's "Every Icon" when audiences are confronted with the fact that the program has been running for decades, responses like, "this has run longer than my marriage," or, "I was still in high school when this started" , or "I wasn't even born yet," are likely. The method enlists the user to insert their personal experience as a mode of comparative analysis, thereby leveraging the whole of their being as their basis of scale. We might even say that this is the largest possible anthropic unit: life in totality.

Rather than attempt to tell the story of the entire internet (as in the case of Jevbratt) or simultaneously render each and every icon (as in the case of Simon) by reducing its complexity and thus making 'user-friendly', they resist. Instead these data visualization designers present to their audience the true complexity of their subject matter within a narrowed, digestible human-sized frame. As a technique I liken it to standing along the shore, allowing the waves to crash over you as a means of knowing the ocean: violent and overwhelming, and authentic in its conveyance and allusion of force.

Yes, they may overwhelm. But their value lies in their ability to engage and implicate their audience at a holistic experiential level, thereby widening the occupiable space of meaning and the field against which comprehension may be mapped.

2.2 On The Utility of the Brute Force Sublime

I argue that there is intrinsic value in understanding that you do not understand. While full comprehension of the true extent to which we do not understand may be forever unattainable, visualizations of vast numerical range can help us to narrow the gap between Kantian mathematical and aesthetic sublimes: the knowable, and the comprehensible. Further, the cognitive limitations of our capacity to understand large numbers and vast distances can have very direct social costs: great underestimations of time, cost and resource requirements to satisfy any variety of projects, efforts, and social and political expenditures.

In 1979, The Vietnam War veterans' committee, empowered by Congress, was granted the right to construct a memorial on the Mall in Washington, D.C., commemorating the deaths of U.S. soldiers in Vietnam. Among the more than 1,400 submissions, Maya Lin, a 20-year-old Yale undergraduate proposed a sunken wall of reflective black stone, with the names of nearly 58,000 soldiers killed in action, engraved chronologically across its facade.[17] While the memorial received a degree of criticism when initially announced, it has become one of Washington D.C.'s most frequented destinations due the to extraordinary impact it has on its viewers. Here, a New York Times article

[17] "Maya Lin's Vietnam Veterans' Memorial." PBS. Public Broadcasting Service, n.d. Web. 04 Apr. 2017.

from the formal acceptance of the privately funded memorial, describes President Reagan's own response to the work delivered at its presentation ceremony.

> *The President's voice fell as he made what has by now become a common, often awestruck, comment of visitors: that each person's reflection in the dark, polished stone of the memorial wall seems to embrace the names of the dead inscribed there.*[18]

While the reflective surface is an effective measure of engagement. The memorial's successes are drawn from the utility of its numerosity. While the sheer volume of names is ostensibly beyond viewers' ability to get their minds around the unique individuality of each name, there is nonetheless the arrival at a unique understanding by the viewer to reveals the underlying nature of the massive cost of the Vietnam conflict. It is a cost that could not effectively be expressed otherwise through the aggregation and visual compression of these names into an alternate visual medium. Here, Rebekah Hobbs, describes this effect in her article published in the *Digital Literature Review*:

> *Many visitors come to the wall to find a specific name, but the sight of all the names amplified along the length of the wall is often sobering...The names reach out to us on a personal level because we identify so closely with our own name. We condense our identity into our names; conversely we are able to expand the names in the memorial into people.*[19]

Here Hobbs points to this critical aspect of personalization I allude to earlier in this essay. In order to connect to a visualization representing mathematical sublimes, audiences derive value from the experience to the extent that they are able to contextualize their own experiences within the frame of the sublime. Hobbs continues:

> *The Wall opposes our binary understanding of death and life by bridging the gap between the two, allowing the names and memories of the dead to inhabit the same space as the living. This does not occur passively, but the design of the memorial specifically contributes to the link between the living and the dead.*[20]

In the intersection of numerosity perception and personal experience, deliverances of the mathematical sublime more firmly establish a foothold in immediacy, thereby presenting social value, and create actionable meaning in the relationship between viewer and subject matter. For a more current example, we need look no further than a key campaign promise made throughout our most recent presidential election.

Repeatedly, at rallies throughout 2016 presidential election campaign, nominee Donald Trump reiterated a his intent to build a thirty foot wall along the US/Mexico border. Given its winding stretch, in order to deliver on this promise, nearly 2,000 miles of wall would need to be constructed from the Gulf of Mexico to the Pacific Ocean. While much of the fervor over this prospect may have been driven by xenophobic, nationalist impulses, belying those impulses must exist some inclination toward pragmatism that is betrayed. Underneath that fervor is buried some basic misunderstanding of feasibility and reasonableness. I put forth here that this misconception is at least in some manner attributable to a failure to effectively comprehend the meaning of that distance. Given that the value '2,000 miles' so exceeds typical experiential interactions with a landscape, there is a fundamental failure of interpretation to consider this a feasible or in any way a pragmatic pursuit.

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[18]BEN A. FRANKLIN, "PRESIDENT ACCEPTS VIETNAM MEMORIAL," Special to the New York Times; November 12, 1984

[19] Rebekah Hobbs A Place to Mourn: Why the Vietnam Veterans Memorial is Crucial to American Healing, Digital Literature Review vol 1 (2014) Ball State University

[20] Rebekah Hobbs A Place to Mourn: Why the Vietnam Veterans Memorial is Crucial to American Healing, Digital Literature Review vol 1 (2014) Ball State University

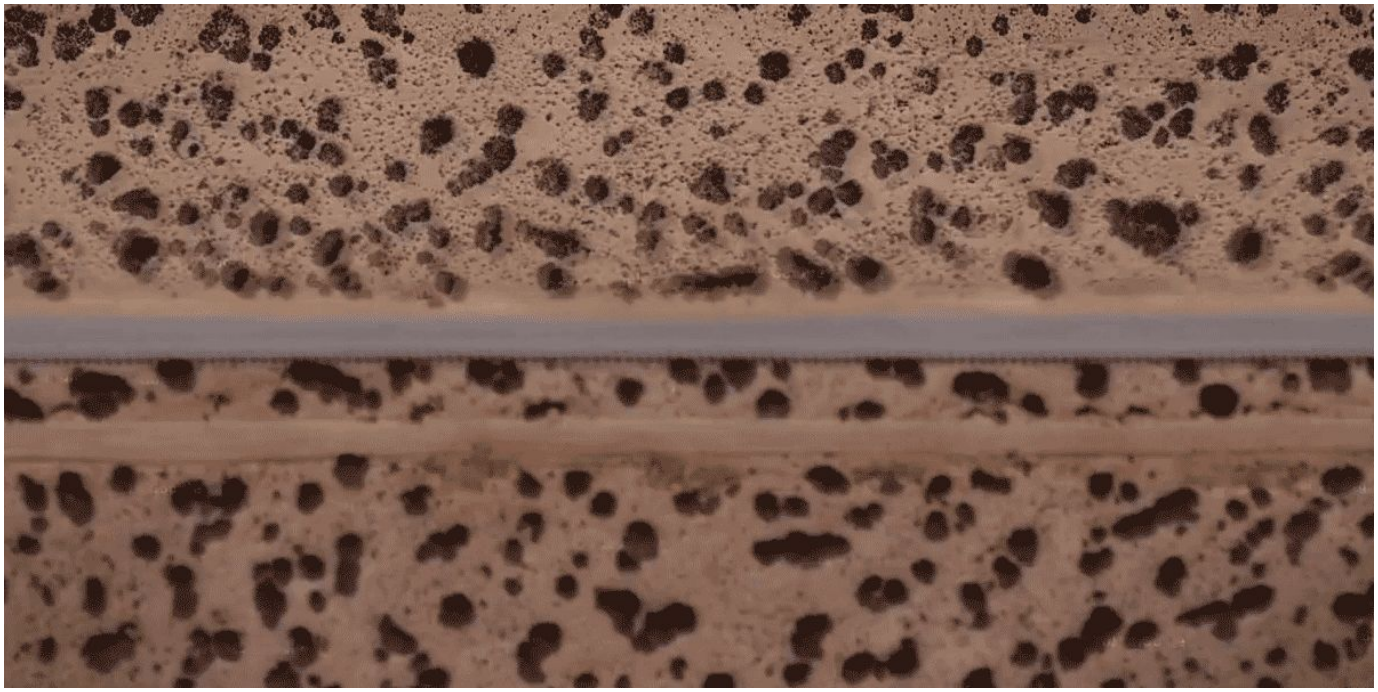
Self-described as, “a filmmaker-driven documentary unit that commissions and creates original short-form nonfiction films about developing and ongoing stories around the globe,” the group Field of Vision created a six minute 41 second video visualizing this distance from point A to point B in a project called “Best of Luck with the Wall.” In the video, viewers are presented with some 200,000 satellite generated image stills animating the physical distance of the proposed wall. The images flashing by at an ever-increasing rate first orient, then overwhelm, and disorient with a dizzying barrage of images. What it illustrates is the absolute prohibitive enormity of such a project in a way that few of the border wall’s proponents are likely to have engaged.

The film’s director, Josh Begley, in an interview describes the project’s core aims:

> *The project started from a really simple place. It was about looking. It was about the sheer desire to understand the visual landscape that we are talking about when we are talking about the southern border of the United States. What does the southern border of the United States actually look like?* [21]

In capturing the sheer vastness of this space, Begley does something more. He subjugates physical space. Brings it to a fully articulated state. Gives it a name, transposing it from the abstract into artifact. By offering up an experience of the border in this raw form he makes possible some differentiation between its geographic and political attributes.

> *I think that there’s a way in which, with the rise of the Donald [Trump], that space is not even a geography anymore. That space has been reduced to metaphor. So the simplicity of the gesture is about insisting on that geography and simply looking at this vast landscape that gets reduced to this sound bite about building a wall.* [22]


[23]

The effectiveness of the projects is derived precisely from it resistance to compression, from its insistence that the subject matter be represented in the most direct manner available.

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[21] Begley, Josh. "Interview with Josh Begley, Director of Best of Luck with the Wall." Interview by Eric Hynes. Field of Vision. N.p., 26 Oct. 2016. Web. 04 Apr. 2017.

[22] Begley, Josh. "Interview with Josh Begley, Director of Best of Luck with the Wall." Interview by Eric Hynes. Field of Vision. N.p., 26 Oct. 2016. Web. 04 Apr. 2017.

[23] Begley, Josh. "Interview with Josh Begley, Director of Best of Luck with the Wall." Interview by Eric Hynes. Field of Vision. N.p., 26 Oct. 2016. Web. 04 Apr. 2017.

Of the techniques I have examined thus far there are some primary technique's that are demonstrated as effective in dealing with sublime and dynamic mathematical representations. Primary among them are the resistance to representational compression and the implication of user experience. The resistance to representational compression suggests that work exploring this field need not reduce the complexity of the subject matter, but embrace it, as in the case of Begley. While the viewer's direct experience of the full scale of the project may be prohibitive and outright overwhelming, as in the case of Jevbratt and Simon, 'slicing' is often effective way of allowing a microcosmic extract to make allusion to the whole. Secondly, as a way of bridging this cognitive gap, data visualizations dealing with the sublime do well to invoke personal narrative and experience of the viewer in order to connect the mathematically vast to the aesthetically accessible. These principles and practices will be at the core of the Wave9 mobile experience, as the model itself will not be experienced in a single visual expression, allowing the experience to employ the full complexity of the model in its entirety. Additionally the Wave 9 model will maintain an immersive relationship to its view, and evocation of experiential infusion will inform that representational frame and interpretations of the model itself.

2.3 The Affordances of Augmented Reality

In the final passages of my treatment I will explore how augmented reality space is ideally suited to accommodate those design considerations and representational techniques. Further I argue that augmented reality provides additional advantages with regard to overall comprehension and cognitive stickiness of the learning outcomes. In short, the build of large scale models within the augmented space provides various opportunities unique to the augmented reality medium. Here, I explore some of these affordances.

2.3.1 Personalization, control, and role play

A powerful argument in support of the augmented reality medium is it unique ability to engage its audiences in the subject matter display through the direct material control over digital layer interfaces. Numerous studies have supported the argument that personalization and control demonstrates greater levels of engagement and user comprehension, enhancing user learning. Through interactivity in augmented spaces user learning is uniquely affording of direct control via material interaction, thus allowing users to test understandings about the relationships between 3D objects, correct their misunderstanding, refine and retest (Shelton and Hedley 2002) [24].

Shelton and Hedley conducted their research, testing learning outcomes of sun-earth relationships as it relates to orbit, rotation, and axis. In their study they found that the specific ability of users to test assumptions about the sun-earth relationship within the augmented 3D model allowed audiences to test their hypothesis, and refine their testing in real time, demonstrating real world properties of the sun-earth relationship.[25] Another such study with a similar determination used AR technology to model molecular structure (Fjeld M, Schar S, Signorello D, Krueger H2002), and demonstrates increased levels of comprehension through material interaction [26]. In this case again the streamlining of information through the digital layer, allowed users to access the physical properties of their subject matter directly, removing intermediary passages of information.

In learning scenarios unsupported by augmented reality modeling, you might imagine that a question first needs to be formulated. The respondent might then be obligated to repeated/restate the question as to validate the accuracy of their comprehension. Once that information is received by the questioner, their comprehension is then tested through a restatement of the underlying concept expressed, and then validated by the respondent. In interactions with augmented reality models, much of these exchanges of information are

[24] Shelton B, Hedley N (2002) Using augmented reality for teaching earth-sun relationships to undergraduate geography student. In: The first IEEE international augmented reality toolkit workshop. Darmstadt, Germany

[25] Shelton B, Hedley N (2002) Using augmented reality for teaching earth-sun relationships to undergraduate geography student. In: The first IEEE international augmented reality toolkit workshop. Darmstadt, Germany

[26] Fjeld M, Schar S, Signorello D, Krueger H (2002) Alternative tools for tangible interaction: a usability evaluation. In: IEEE and AMC international symposium on mixed and augmented reality

rendered needless, empowering the user to answer their own questions through the manipulation of the model and through interactions with its parts.

Furthering this idea, a 2006 study of the use of AR found a key character informing the success of augmented reality learning (Kerawalla et al 2006)[27]. In their research they argue that role-play and free exploration was a key component to maximizing learning outcomes (Kerawalla et al 2006)[28]. In their experiment Kerawala and Seljeflot measured learning outcomes from two different learning groups. In one instance, instructors used augmented reality as a means of demonstration. In other instances, instructors who leveraged use of augmented reality as a tool for role-play showed higher levels of engagement from their students.[29]

Any model developed within the 3D augmented reality sphere of interaction, requires interactive components that support this level of exploration and user hypothesis testing. In order for the model to engage the user at the level of meaning, the model must conform to determined and testable range of physical properties within the digital sphere of user interactions.

2.3.2 Interspatial poetics: the symbiosis of meaning

It is important to note that at the time of aforementioned studies, augmented reality was still very much in its infancy. Some of the barriers to use included the relative clunkiness of the hardware, often requiring headsets, numerous wires, and specialized interactive display boards. With the advances in augmented reality technology in the last ten years, the liberation of space and relative low cost of augmented reality capable devices, a literal landscape is now available to possible use.

It is around the time that those studies were taking place that Manovich began to imagine the liberation of that space in his essay, “the poetics of augmented space,” to further the use and interflow of environmental and digital spaces. In his article, he points to the work of a Canadian artist Janet Cardiff who created works he refers to as ‘audio walks’ that guide a viewer through a space augmented by an audio narrative.

> *In my view -- even though Cardiff does not use any sophisticated computer, networking, or projection technologies -- her ‘walks’ represent the best realization of the augmented space paradigm so far. They demonstrate the aesthetic potential of laying new information over a physical space. Their power lies in their interaction between the two spaces -- between vision and hearing (what the users are seeing and hearing), and between present and past (the time of the user’s walk versus the audio narration, which, like any media recording, belong to some undefined time in the past).*[30]

Given that the effectiveness of learning outcomes is tied to the level of user engagement experienced by users, the delivery of the augmented reality model, should create a kind of interdependence of layers. While the digital layer will certainly need to conform to the properties of the physical environment, so too must the physical environment be leveraged in such a way as to appear as though it depends on the physical layer, positioned so as to infuse with meaning the entirety of the environment and the objects within it, so that everything from city blocks to fingernails may be referenced as units of measure, and the experience of the users may be inserted into the digital/environmental aesthetic interplay.

Given the representational demands of extreme scale values, continued efforts to characterize the sublime in new modeling modeling techniques must fully utilize all possible elements to which meaning may be mapped

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[27] Kerawalla L, Seljeflot S, Luckin R, Woolard A (2006) “Making it real: exploring the potential of augmented reality for teaching primary school science, Springee-Verlag London Limited (2006)

[28] Kerawalla L, Seljeflot S, Luckin R, Woolard A (2006) “Making it real: exploring the potential of augmented reality for teaching primary school science, Springee-Verlag London Limited (2006)

[29] Kerawalla L, Seljeflot S, Luckin R, Woolard A (2006) “Making it real: exploring the potential of augmented reality for teaching primary school science, Springee-Verlag London Limited (2006)

[30] Manovich L, (2006) The Poetics of augmented space, Visual Communication Vol5(2), SAGE Publications (London, Thousand Oaks CA and New Delhi

and eventual derived. Through this perspective, I put forth that augmented reality as a modeling tool is ideally suited for such representations. By building models in 3D augmented spaces there is opportunity to create meaning beyond the mere overlay of digital layers, but an opportunity to infuse native physical space with representational meaning, thus conceptually transforming the physical landscape.

For example, if a model of the solar system were to be mapped over New York City, one city block might be mapped to five light-minutes. Therefore, even in the moments where the viewer does not have a direct material interaction with the digital layer of augmented space, its mappings continue to be meaningfully rendered and accessible in the viewer's experience through the reconceptualization of the familiar physical environment. In the spirit of anti-sublime representations this provides opportunity to retain the underlying complexity of the subject matter while maintaining user engagement and cognitive aesthetic accessibility. This is an impulse anticipated by Manovich in his examination of the sublime in data art.

> *In the 1960's the late Surealists -- the Situationists -- developed a number of methods for their "the derive" (the drift). The goal of "the derive" was a kind of spatial "ostranenie: (estrangement): to let the city dweller experience the city in a new way and thus politicize her of his perception of the habitat...This is a kind of poetry and conceptual elegance I find missing from mapping projects in new media art...to reinterpret the often banal and seemingly insignificant images of everyday life...*[31]

Mapping such large models in this manner explodes the representational canvas and accordingly opens up new opportunities for value representation. Further the immersion of the viewer within the physical model enhances the viewer's cognitive abilities to maintain a coherent thread of understanding of its scale as each dimension of its space is physically accessible in a direct manner without compromising the accessibility of the whole.

As John Simon's use of time in Every Icon entices audiences to draw upon personal experiences to infuse the work with meaning, so too can this method be leveraged in augmented space. While a distance of one mile is difficult to view without extracting oneself from the immediate physical/augmented space, anyone within an immersive representational model, such as the model described, similarly maps meaning beyond the digital layer, but also to what is not displayed. While an individual may not be able to experience an entire mile of a model comprehensively and directly in a simultaneous manner, users have comprehension of what the distance of a single mile *feels* like. Whether that is understood in terms of hilltops or city blocks is irrelevant. What matters is the transposition of the banal, the leveraging of the lived experience of distance into the representational, metaphorical meaning. It is a means of employing the 'slicing' technique of the anti-sublime, allowing unfiltered microcosms assume representational vastness.

2.3.3 Cognitive expansion and the complementary artifact

To outline the potential value in modeling in this manner, I want to consider a concept put forth by biologist David Krakauer, president at the Sante Fe Institute. Krakauer in his research categorizes technology in all its variations in one of two buckets: *complementary cognitive artifacts* and *competing cognitive artifacts*. The concept addresses the manner in which we relate to objects and tools in our environment. His claim that some cultural artifacts serve to enhance our cognitive abilities by rewiring the brain to maximize cognitive efficiency, whereas competing cultural artifacts actually make us dumber. For instance, with a calculator, anyone can calculate complex mathematical caculations in mere seconds. While the output and accuracy is highly efficient, take that calculator away from the individual and the unpracticed mind becomes incapable of even simple arithmetic. On the other hand, if you were to consider the process of long division as a cultural artifact, the internalized process actually rewires the brain in such a way as to create expanded cognitive capacity. Here Krakauer explains:

[31] Lev Manovich, "Data Visualization as New Abstraction and Anti-Sublime" (2002) accessed March 15, 2017, http://manovich.net/content/04-projects/040-data-visualisation-as-new-abstraction-and-anti-sublime/37_article_2002.pdf

The other example that I'm very enamored of is the abacus. The abacus is a device for doing arithmetic in the world with our hands and eyes. But expert abacus users no longer have to use the physical abacus. They actually create a virtual abacus in the visual cortex. And that's particularly interesting, because a novice abacus user like me or you thinks about them either verbally or in terms of our frontal cortex. But as you get better and better, the place in the brain where the abacus is represented shifts, from language-like areas to visual, spatial areas in the brain. It really is a beautiful example of an object in the world restructuring the brain to perform a task efficiently—in other words, by my definition, intelligently.

Maps are another beautiful example of this. Let's imagine we don't know how to get around a city. Over the course of centuries or decades or years, many people contribute to the drawing of a very accurate map. But if you sit down and pore over it, you can memorize the whole damn thing. And you now have in your mind's eye what it took thousands of people thousands of years to construct. You've changed the internal wiring of your brain, in a very real sense, to encode spatial relations in the world that you could never have directly experienced. [32]

I put forth in this research the augmented reality visualization development is ideally suited to functional at the level of a complementary cognitive artifact. Whereas there are expansive numbers of mobile applications that create efficiency and straightforwardness of use of data, few actually work to create cognitive capacity. For example the numerous navigation maps available on mobile platforms simplify the navigation experience. One need only listen to the explicit turn by turn instruction of their favorite sit-com actor, and they will arrive at their destination, confident of having traveled the move efficient route, leveraging all available traffic and road activity data in real-time. There is a cost to this efficiency however.

The competitive cognitive artifact of the navigation apps, removes the user from comprehension of environment and the greater context of their movement. As our navigational abilities are diminished, so too is the cognitive capacity derived from map-reading. While these tools have their place the affordances of mobile augmented reality permit uses that can build cognitive capacity. In particular, by mapping objects of expansive spatial relationships, (ie the sublime) to a physical environment, users more directly connect to those relationships in meaningful and enduring ways.

The relative cognitive longevity of spatial narrative and the cognitive capacity building is derived in large part from the apparent depth of connectivity between space and memory. This relationship is one that has been explored and celebrated for its unique cognitive capacity building propensity as far back as ancient Greece. The technique is called Memory Palace or the Method of Loci. The practice is simple: construct a path through a physical space (traditionally a space familiar to the user) and construct a narrative that associates specific targets of memorization with checkpoints along the path.

While there is much anecdotal evidence to support the effectiveness of the technique, worth noting is the volume of scientific research into the effectiveness of the technique. Further while the general practice of the method promotes imaginative use of a familiar space, Legge et al (2012) have conducted research supporting claims that the mnemonic device may be more variously applied the traditionally conceived. In their experiments they have verified along with numerous other studies, elevated memory recall among of experiment subjects employing this mnemonic device in comparison to control groups. Their study is interesting for yet another reason however. Whereas the traditional practice of the mnemonic device relies on use of a familiar environmental space through which the mnemonics narrative structure is wound, Legge et al found elevated memory recall among subjects utilizing alternate digital/virtual environment. Further comparing subjects employing the traditional technique, their study found that use of digital/virtual environment show no attenuation[33].

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[32] Harris, Sam. "Waking Up." Audio blog post. Complexity & Stupidity. Sam Harris, Web. November 13, 2016

[33] Legge, Eric, Madan, Christopher, Ng, Enoch, Caplan, Jeremy, "Bilding a memory palace in minutes: Equivalent memory performance using virtual versus conventional environments with the Method of Loci" Acta Psychologica 141, 2012

Leveraging physical space as a means of constructing narrative, further allows the Wave 9 mobile application to serve as a complementary cultural artifact in the it results in cognitive stickiness of the concepts and spatial relationships represented within its model.

CONCLUSIONS

In conclusion, the research compiled and analyzed in the essay support the development of the Wave 9 mobile application in the following ways. First the research acknowledges the fundamental transformation of representational allowance of the sublime promoted by new media technologies. Second, critical representational parameters are established in new media visualization that allow us to render the sublime while a) maintained underlying complexities of the subject matter, while preserving aesthetic accessibility. These ‘slicing’ techniques include: time-based elongation (Simon), time-compressed spatial rendering (Begley), subset parameter framing (Jevbratt), spatial-experiential interaction subsetting (Lin). The Wave 9 mobile application borrows primarily from the Maya Lin example where spatial-experiential interaction subsetting relies on micro-user experience with the model to derive and infuse meaning through spatial interaction, but shares the underlying strategy of anti-sublime data visualizations by resisting compression of the subject matter’s underlying complexity. The use of the augmented reality platform is found support learning outcomes, cognitive understanding, and user engagement by intuitive test/error correction interactions via manipulation, movement, and control throughout physical space. Lastly, demonstrated connectedness of memory and physical space support the aim of the project to create a cognitive stickiness thereby serving audiences as a complementary cognitive artifact.