

Data Moiré: Optical Patterns as Data-Driven Design Narratives

Alvin Huang, AIA

Associate Professor, USC School of Architecture
Founder and Design Principal, Synthesis Design + Architecture

Anna M. Chaney

IBM Watson: Advanced Cognitive Technology & Solutions

ABSTRACT

Big Data (data sets so complex or expansive where conventional data processing is insufficient) has continually had a big impact. It is affecting the worlds of commerce, media, and design, amongst many others, and more recently it is becoming an industry in itself. This paper documents the research and design process of *Data Moiré*, a large-scale feature wall designed and installed for the IBM Watson Experience Center in San Francisco, California. The project merges the territories of “data spatialization” and “data narrative” by using the cognitive computing capabilities of IBM Watson to inform a data-driven generative design processes. The result is a digitally-fabricated physical installation that illustrates monthly spending cycles by mapping the growing influence of mobile devices on all digital sales from 2013–2015. The data is materialized as a CNC-milled, double-layered aluminum, back-lit screen wall, producing a moiré-like effect through abstract visual interference patterns generated by the overlaying of two mappings of the same data set.

The resultant project is simultaneously an abstract representation of Big Data that offers a uniquely spatial

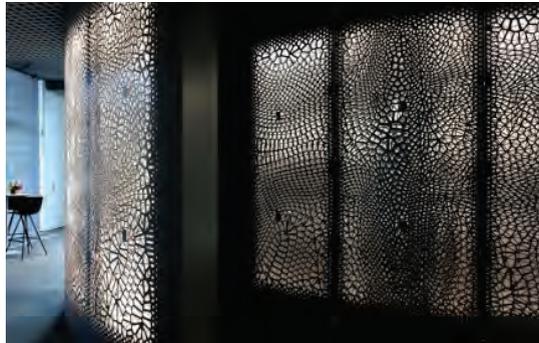
marketing narrative, as well as a dynamic architectural feature with a visual experience that is amplified through the movement of visitors through the Experience Center. The paper reviews initial research and data mining, digital mapping and visualization studies, and the development of tectonic including spatial logics which have proved effective both representationally and atmospherically.

1 INTRODUCTION

Big Data (data sets so complex or expansive that conventional data processing is insufficient) has continually had a big impact. It is affecting the worlds of commerce, media, and design, amongst many others, and more recently, it is becoming an industry in itself. IBM Analytics has emerged as the leading commercial technology platform for uncovering insights into large quantities of highly curated unstructured data.

Similarly, recent conversations in architectural discourse have theorized on the emergence of data-driven design as a paradigm shift, one that leverages computation in using the expansiveness of Big Data to conceive of an architecture that is understood as the registration of “reality as it appears at any chosen scale, without having

Figure 1: Entrance to the Immersion Room at the IBM Watson Experience Center.



growing influence of mobile devices on all digital sales from 2013–2015. The data is materialized as a CNC-milled, double layered aluminum back-lit screen wall that produces a moiré-like effect through abstract visual interference patterns produced by the overlaying of two mappings of the same data set. This screen wall is used as the cladding for the Watson Immersion Room (fig. 1).

The result is a dynamic architectural feature that provides identity and enhances the visual and spatial experience of visitors to the Watson Experience Center, while simultaneously providing a uniquely spatial marketing narrative that highlights Watson’s ability to analyze large quantities of unstructured data.

2 PRECEDENTS

Several important precedents were referenced and studied to inform the research, design, and development of the project. Many examples were studied and explored in the field of data visualization, and in particular, the precedent of highest importance was the “Centennial Chromograph,” by Adam Marcus/Variable Projects. This large-scale installation not only extends the trajectory of data visualization toward data spatialization by physically representing statistical data spanning 100 years in the institutional history of the University of Minnesota School of Architecture, but it also focuses on the abstraction of the data as a means of producing atmospheric effects. Additionally, the work of British Op artist Bridget Riley was further referenced, specifically her studies of variable, non-repetitive two-dimensional patterns that give the illusion of three-dimensional depth and movement.

3 DESIGNING DATA

In an effort to showcase the capabilities of their cognitive computing services, IBM is launching a series of showrooms known as Watson Experience Centers (WEC), with each center focused on a particular commercial market. Current centers exist in New York City and Cambridge, with our project located in the San Francisco WEC and focusing on the retail and commerce industries. The focal point of each WEC is the Immersion Room, an immersive media space where clients of IBM can experience Watson technologies as a visually stunning complete environment. Each WEC Immersion Room is a small circular room floating within an open floor plan. We were commissioned to design the custom exterior cladding for the San Francisco Immersion Room. The brief provided by IBM was simple: to design a custom wall, with a maximum depth of six inches, that would provide a unique identity for the center.

In response to the brief, we proposed a collaborative design approach that challenged IBM to utilize Watson’s cognitive computing capabilities to provide us with relevant data analysis to drive our generative design processes. The intent was to consider the feature wall as a physical representation abstracted from a chronological

to convert it into simplified and scalable mathematical notations or laws” (Carpo 2014). The term “data spatialization” has emerged to describe novel architectural materializations that utilize computational design processes to generate novel architectural expressions and spatial opportunities informed by Big Data (Marcus 2015).

In parallel, the media world has witnessed the emergence of a new form of storytelling as “Data Narrative,” whereby the crafting of stories happens through the collection and analysis of new or existing sets of Big Data. These data stories utilize data visualizations embedded with narrative components to produce a form of narrative visualization that tells a story through the analysis of data (Segel and Heer 2010).

Data Moiré is a large-scale, data-driven feature wall that merges the territories of data spatialization and data narrative. It uses the cognitive computing capabilities of IBM Watson to inform a data-driven generative design process to articulate a vast quantity of data as a spatial experience and marketing narrative for the IBM Watson Experience Center in San Francisco, California. The result is a digitally fabricated physical installation that illustrates monthly spending cycles by mapping the

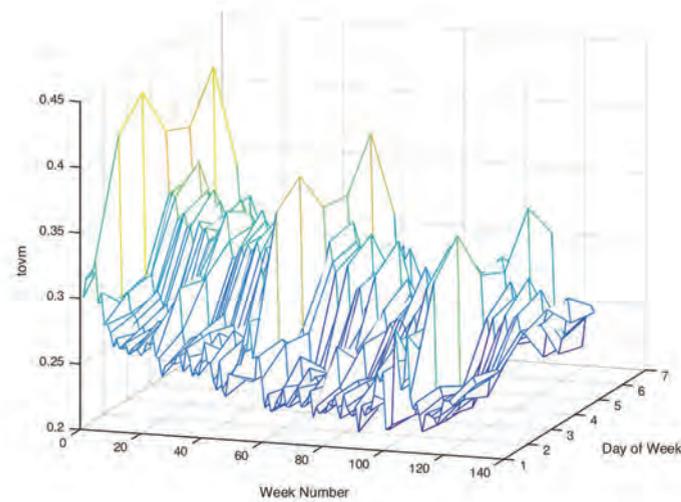


Figure 2: Surface of tovm values.

set of Big Data that on its own provided an iconic identity for the center. However, when the wall is experienced as part of a guided tour and explained by a docent, the skin could be utilized as the physical manifestation of narrative visualization, thus providing a powerful analytical, creative, and narrative tool in revealing new ways of comprehending, navigating, and experiencing information (Schneider 2015). To achieve this task, IBM chose a data set that would express the changing face of e-commerce, and the growing influence of mobile devices on all digital sales.

3.1 Collecting Data

IBM Digital Analytics Benchmark delivers aggregated and anonymous competitive website data. The data is collected by measuring every single interaction on every single participating site, capturing comprehensive behavioral data. For our project, we wanted to express the growing power of mobile devices in digital purchases, and we chose the following data series from the Benchmark data:

- a = Daily average order value in USD
- b = Daily mobile sessions as a percent of sales
- c = Daily total number of orders

The data for each of these series was sampled for 123 weeks, from Wednesday, August 21, 2013, through Tuesday, December 29, 2015.

3.2 Translating Data

Data translation was a three-step process:

1. Collate the three daily series into one metric that expressed the strength of mobile devices on digital sales.
2. Transform the data into a two-dimensional pattern.
3. Interpolate the series to the dimensions of the skin.

The data that needed to be combined are of very different scales, and can be combined using the simple transformation:

$$a * c = \text{daily total order value (tov)}$$

$$\text{tov} * b = \text{daily total order value on mobile (tovm)}$$

To find trends in the tovm data series, we organize the data set into a 7 x 123 matrix, where the rows are days of the week, and the columns are weeks, like so:

DAY OF WEEK DAILY ALIGNMENT FOR TOTAL ORDER VALUE ON MOBILE DEVICES

Tuesday:	29 Dec 2015	...	3 Sept 2013	27 Aug 2013
Monday:	28 Dec 2015		2 Sept 2013	26 Aug 2013
Sunday:	27 Dec 2015		1 Sept 2013	25 Aug 2013
Saturday:	26 Dec 2015		31 Aug 2013	24 Aug 2013
Friday:	25 Dec 2015		30 Aug 2013	23 Aug 2013
Thursday:	24 Dec 2015		29 Aug 2013	22 Aug 2013
Wednesday:	23 Dec 2015		28 Aug 2013	21 Aug 2013

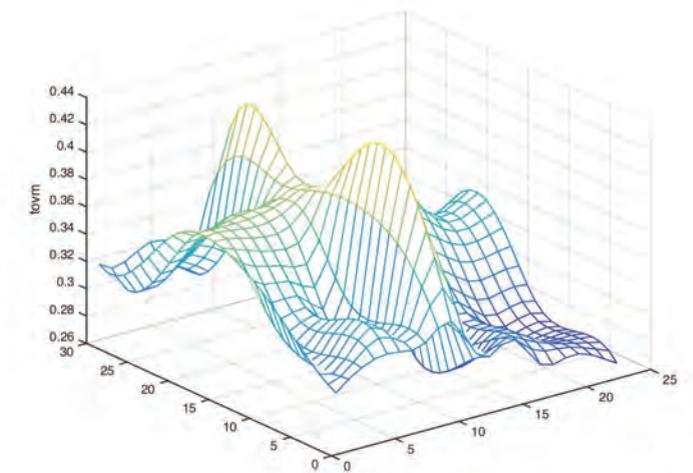
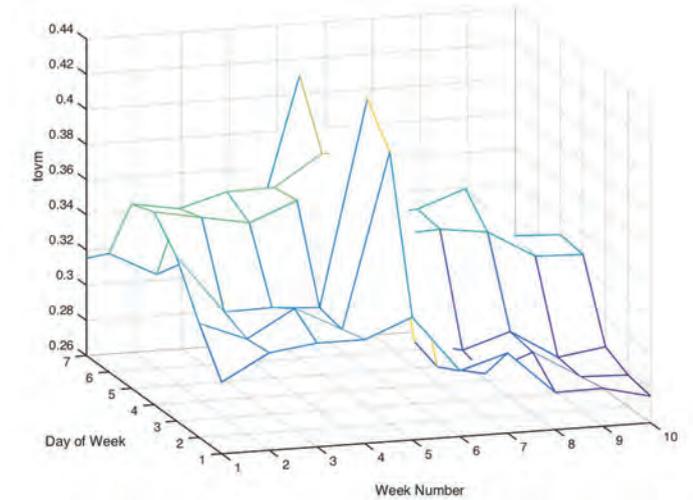


Figure 3: Last 10 weeks of data before cubic spline interpolation (top) and after (bottom).

Using the guide from this table, we then create a surface using the position in the matrix as the (x,y) coordinate, and the tovm value at that day as the z coordinate (fig. 2).

Now, there are several interesting patterns that have started to appear in the data. We see three specific weeks that stand out from the rest of the data set as lateral peaks. These are the weeks containing Thanksgiving, Black Friday, and Cyber Monday. The other pattern visible is a stronger mobile usage for digital commerce on the weekends, as opposed to the weekdays, which reads as a longitudinal intensity across the length of the pattern.

At this point the raw data pattern has two problems:

1. The skin has an aspect ratio of 30 x 280, while the data set has an aspect ratio of 123 x 7.
2. The legibility of the data set is hard to interpret with the hard peaks and jagged edges.

To solve these problems, we resample the surface on the finer using cubic spline interpolation to find the new data points. This solves both size and clarity issues for

Figure 4: The final data set used to inspire the skin design.

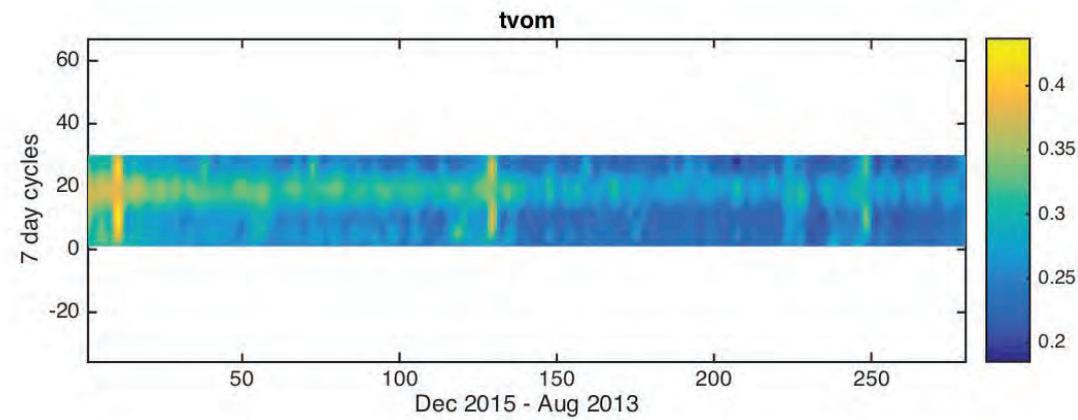
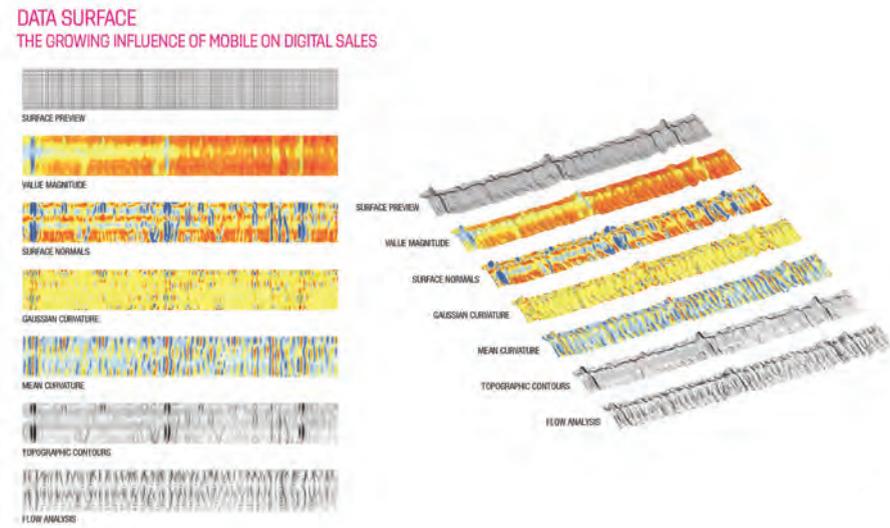


Figure 5: Processing raw given data into producing the patterned networks.



the pattern (fig. 3). Now, the data set for the whole skin can be seen in Figure 4, looking down on the surface and visualizing the z-height as a heat map.

4 DESIGNING FROM DATA

This raw quantitative data was provided to the design team as a three-dimensional data surface produced in the multi-paradigm numerical computing environment MATLAB to illustrate the distribution of digital sales as a chronological continuum of peaks and valleys. The next challenge was to materialize the varying intensities of this three-dimensional data within a six-inch depth. In order to achieve this, it was decided to translate the three-dimensional data surface through the Grasshopper parametric modeling platform as a two-dimensional geometric pattern that could be CNC-milled or laser-cut out of flat sheet metal material to be assembled as a back-lit feature wall. This strategy would allow the three-dimensional data to be compacted to fit within the constraints of the six-inch wall cavity we were provided.

In addition to the physical constraints of depth, we were interested in the ability of geometric patterns to do two things:

1. Adapt their autonomous internal logics to heterogeneous external forces without losing either their organizational or aesthetic identity (Andersen and Salomon 2006).
2. Provide the illusion of depth and motion through variable patterning organizations that produce vivid dynamic illusions that trigger involuntary eye movements (Zanker 2004).

With the previously described design characteristics in mind, a series of design objectives were established as patterning criteria:

1. The materialization should be a two-dimensional pattern that had the legibility of the three-dimensional data surface.
2. The pattern should abstractly express, rather than be a literal representation of, the varying intensities (peaks and valleys) of the data surface.

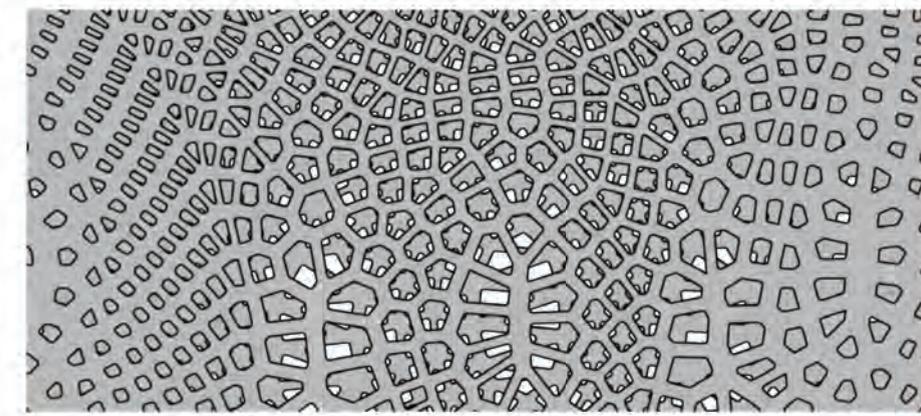


Figure 6: Voronoi network overlaid upon the Delaunay.

VORNOI-DELAUNAY PATTERN MOIRE EFFECT

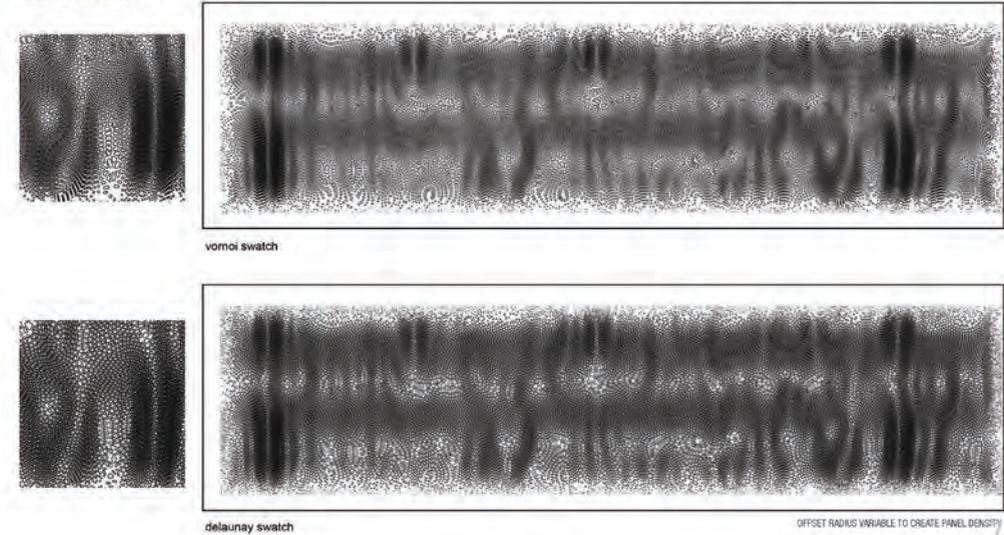
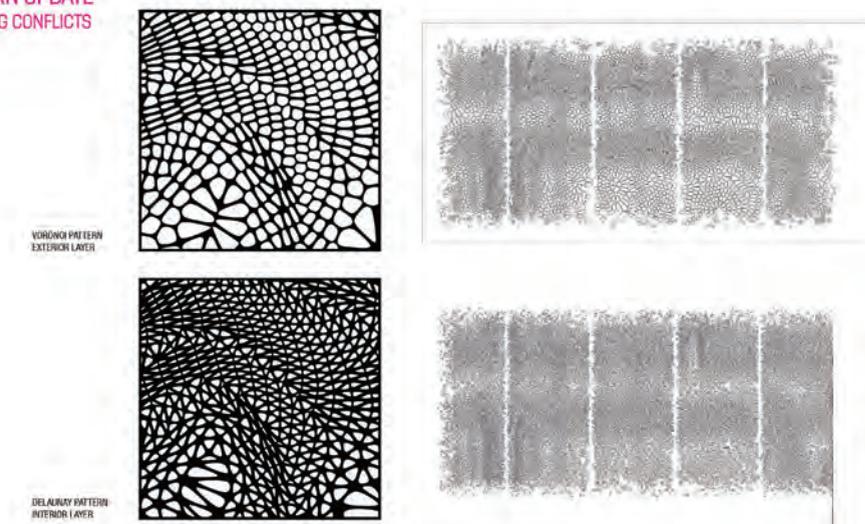


Figure 7: Voronoi and Delaunay pattern shown independently.

Figure 8: Network inherently avoids misalignments and conflicts.

PATTERN UPDATE AVOIDING CONFLICTS





AXON - VIEW 2
SCALE = NTS 3



AXON - VIEW 1
SCALE = NTS 2

3. The pattern should provide a dynamic visual experience that would both encourage visitors to walk around the Immersion Room and appear to be different from each and every vantage point.
4. The pattern should be integrated with all structural requirements.

Based off of the established design criteria, a number of explorations were produced to test various patterning techniques and materialization options for the conversion of the three-dimensional data surface (fig. 5). Following these explorations, a design pattern was selected for further development.

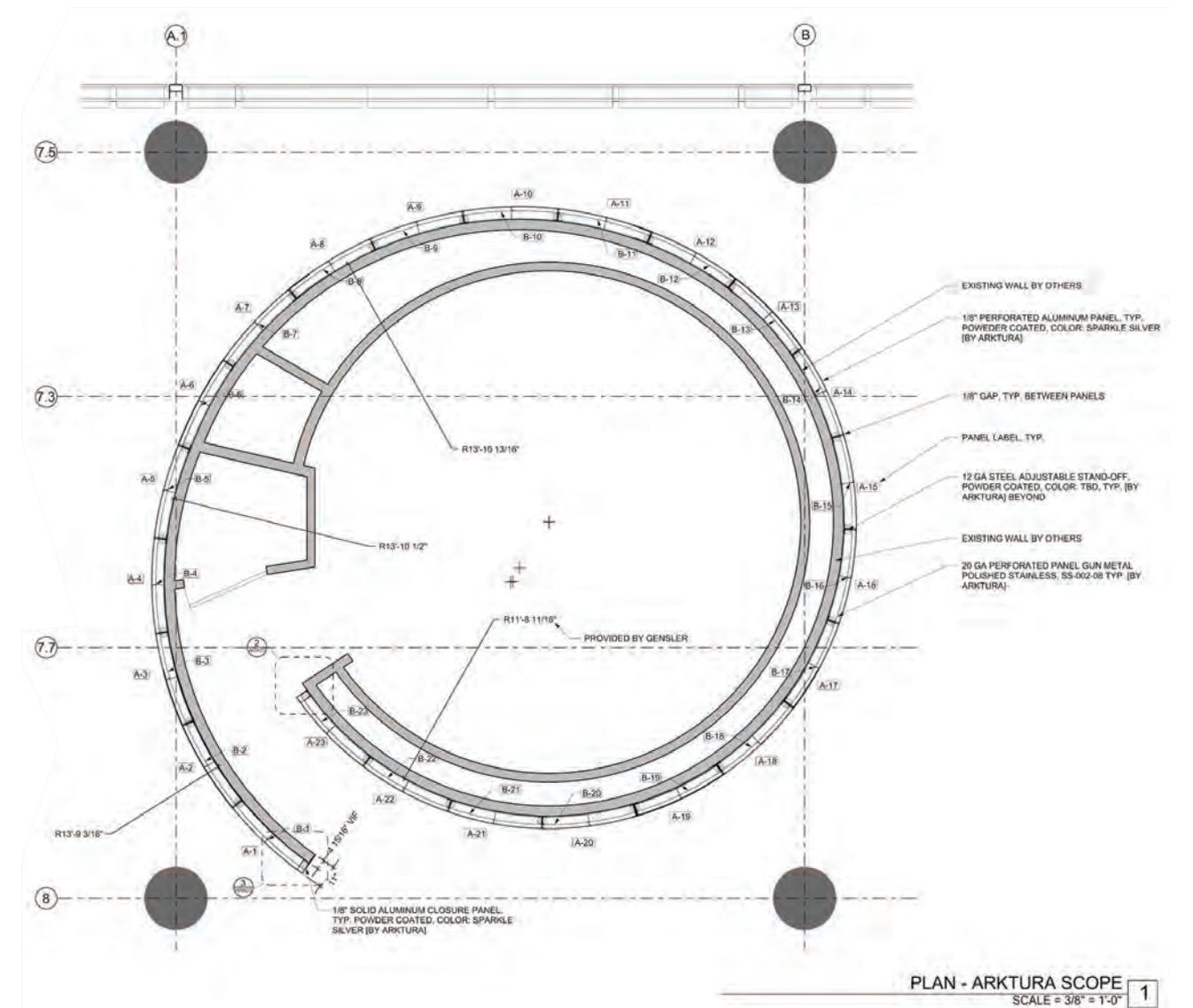
4.1 Patterns From Data

In the tradition of architectural representation, a three-dimensional surface is best described as a two-dimensional

topographical map. In our instance, by sampling the topographical contours of our data surface as a series of evenly distributed points along the length of each curve, that topographical map is translated twice: once as a Voronoi diagram that defines a series of polygonal cells around each point, and once as a Delaunay diagram that defines each point as a node within a network of connections (fig.6).

This translation abstracts the original data surface into two opposing diagrams of solid (the presence of material) and void (the absence of material), each of which is organized to express the varying intensities of amplitude and curvature that are embedded within the original surface, while maintaining a two-dimensional materiality. While the Voronoi diagram creates an arrangement of cellular voids divided by the perpendicular midpoints of their adjacent cells, the Delaunay

Figure 9: Assembled panels in place, cladding the WEC Immersion Room.



PLAN - ARKTURA SCOPE
SCALE = 3/8" = 1'-0" 1

Figure 10: Detail views of CNC-milled and powder-coated exterior skin vs. laser-cut and PVD-coated inner skin.



takes those same points and creates a network of lines connected by them. When overlaid one on top of the other (figs. 7 and 8), the two patterns work collectively to produce a third emergent pattern—one which produces a dynamic visual effect akin to that of a moiré pattern. This visual effect capitalizes on the ability of the moiré to produce an illusion of motion and depth that dynamically engages a viewer and encourages visual interactions through the skin that are exponentially amplified by the viewer's position in space and the variable readings enabled by the alignments, misalignments, and interference patterns produced through the spacing of the two overlaid patterns (Wade 2016).

4.2 Build-a-bility vs. Legibility

The further development of the project required multiple rounds of refinement to the pattern to balance a number of fabrication and assembly criteria (build-a-bility of the installation) against a series of design criteria (legibility of the data within the pattern). Whereas the organization, density, and porosity of the pattern had to be adjusted to contend with the integration of anchor points to the substructure, structural integrity of the individual panels, and visibility of light sources, it was critical not to lose the legibility of the varying intensities within the pattern. In particular, it was key that the dates of Thanksgiving, Black Friday, and Cyber Monday were identifiable as the absolute peaks of intensity within the pattern.

Adjustments were made to the pattern to subtly shift the organization of the pattern to contend with structural

anchor points, reduce the density of perforations to maintain structural integrity, and incorporate a created gradient fall-off condition at the outer edges to conceal the visibility of light sources.

4.3 Fabrication & Finish

The entire assembly is digitally fabricated. The outer layer is CNC-milled out of 1/8-inch cold-rolled aluminum sheet with a silver sparkle powder coat. The inner layer is laser-cut out of 20-gauge steel with a gun-metal PVD coating (fig. 9).

The thicker sheet material on the outer layer enables the sheet to be cold-rolled to an accurate radius to ensure visual continuity between the individual panels, but requires a more expensive process of CNC milling. The thinner sheet material on the inner surface allows a more economical laser cutting process and the ability to bend the sheets to fit on site (while not being concerned about visual continuity since the inner layer is covered), thus further reducing costs. The powder-coated finish on the outer layer enables a durable and easy-to-maintain surface condition, while the PVD-coated finish of the inner layer provides for a highly reflective surface condition that is shielded from fingerprints by the outer layer (fig. 10).

5 BIG DATA, DESIGN SPATIALIZATION, & DESIGN NARRATIVE

While the project is driven by data, the legibility of that data is abstract rather than literal. Instead of a statistical or analytical reading of the data, the project provides a

spatial and atmospheric reading that enhances the experience of visitors to the center and encourages them to engage spatially (fig. 11). It is only through the guided tour of a docent that the legibility of this data is conceded through a verbal narrative. That oral explanation activates the skin to act as more than a narrative visualization—it becomes a narrative spatialization that not only illustrates the findings of the data that produced it (the chronological metrics of e-commerce affected by mobile sales), but also highlights the technology that produced it (the cognitive computing of IBM).

6 CONCLUSION

The data visualisation focuses on beauty, seen as a kind of aesthetic engagement with big data, a form of knowledge encounter that turns on the complexity and aura of an unimaginable object.

—McCosker and Wilken (2014)

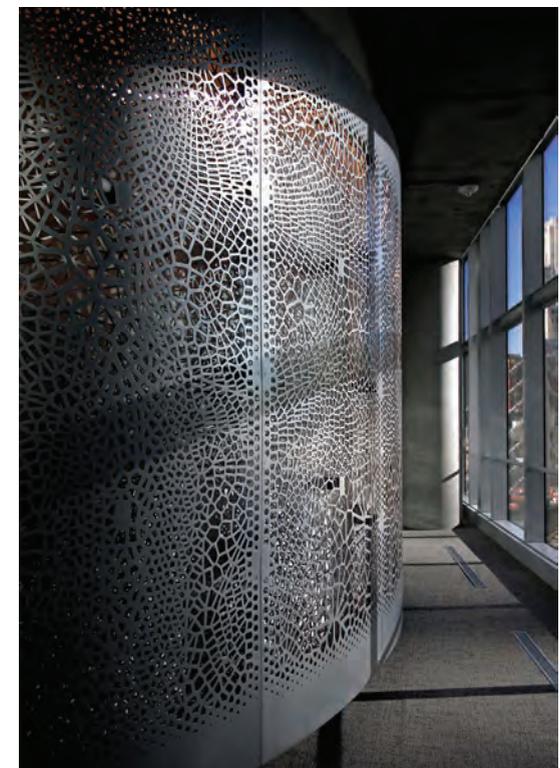
Data Moiré capitalizes on two computational paradigms: the capacity of cognitive computing and machine learning to analyze and provide insights into massive amounts of unstructured data, and the ability of generative design processes to drive geometries that are informed by data. However, it is not the analysis nor the geometries themselves that are the impactful products of this project, but rather the capacity of the analysis and the geometry combined that are able to communicate.

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Figure 11: Photographs of the completed installation.



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