Data Sculpture

[An Alternative Medium of Communication]

Sadie Coughlin-Prego
Earlham College
Undergraduate Computer Science
sadieruth49@gmail.com

ABSTRACT

This paper explores the concept of software-aided data sculpture as an alternative form of communication. Data sculptures create a unique mode of engagement for the user through tangibility, dynamic use of space, and incorporation of aesthetic perception and sensory experience. In order examine the efficacy of data sculpture as a method of provoking critical thought about relationships in empirical data and it's inherent complexities, I have implemented my own. The piece represents recorded data on Latin American migrants traveling to the United States. My intention is that it will captivate the audience and create an emotive and multifaceted experience with the data. My goal in working in the relatively new overlap between software and physical representation is to provoke thoughtful discourse while agitating discussion of solutions addressing social issues, such as those involving the US - Mexico border.

Keywords

Data Sculpture, Computer Aided Design, Communication, Medium, Aesthetics, Physicality, Tangibility, Dimensionality, Cognition, Information Age, Latin American Migration, US - Mexico Border

1. INTRODUCTION

Humans have always had a unique connection to the physical. Our connection to the physical can be used as a medium in which to communicate in today's technologically driven 'Information Age'. The fundamental notion of physicality as a means of representation dates back as far as 5500 BC where the ancient Mesopotamians would use clay tokens in order to externalize and interact with data [1]. Even today children utilize manipulatives and other tangible interfaces (ie. Legos, wooden blocks, puzzles etc.) in order to learn elementary concepts such as mathematics, shapes, and colors [2].

Mesopotamian clay tokens [1].

This paper discusses the ways in which contemporary software-aided data sculpture can utilize the fundamental impact of physicality and tangibility, while also incorporating technology to enhance user's relationship with data. This research will result in the creation of a software-aided data sculpture as proof of concept. I have chosen to represent the current issue of Latin American migration in the U.S. I chose to research and implement a data sculpture because of the contemporary cultural significance of the medium; it widens the scientific framework which data visualization currently occupies by embedding other disciplines, such as art and critical theory. By widening the scientific framework, data sculpture offers new forms of user engagement and interaction. The data becomes more accessible, impactful, and tangible, while still preserving complexity. The emergence of low cost, easy, rapid prototyping and improvements in CAD (computer aided design) software has made data sculpture a subject of contemporary interest in both the arts and sciences.

Since software aided data sculpture is a fairly new, niche, and ambiguous subject, finding information detailing some of the processes involved in creating a data sculpture proved to be challenging. However, I was able to find sufficient information on data sculpture as a concept. In addition, I read scientific papers discussing data modeling within specific fields and explored the works of several artists who design and create data sculptures of their own. Both have been useful in terms of my exploration on the concept, as well as the design and implementation of my own project.

1.1 Motivation: Why is this important?

We live in the 'Information Age'. Information is continuously being recorded both actively by human beings and autonomously by elaborate systems we design. This information is readily at our fingertips through the internet on multiple platforms that we interact with constantly. Despite the huge range of subjects and relationships represented by data, we primarily interact with it through 2D visualizations either on or off our screen-based devices. Our lives have become so visually saturated with continuous screen-based interactions that attention spans have diminished and what remains is competed for monetarily by advertisers [3]. Because of the competition for viewers' attention, the field of data visualization has made data trivial, and quickly absorbable through basic, uncomplicated visuals – even though such information is inherently abstract and conceptually complex. We no longer think hard or critically about that which is presented to us on a screen, especially when presented in simple 2D visualizations [3].

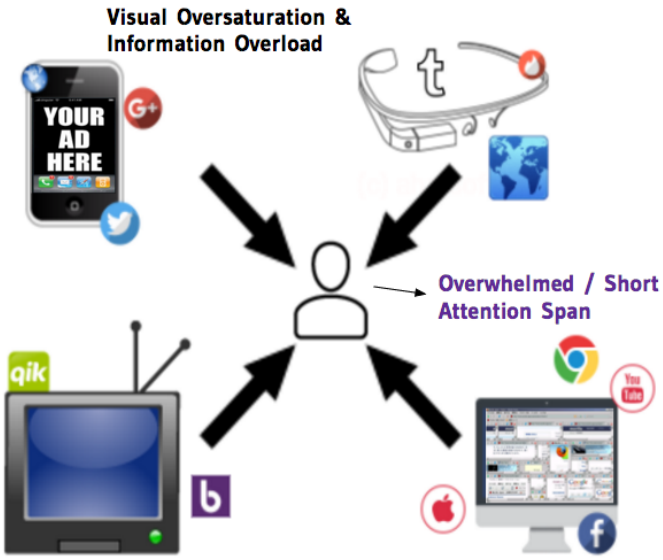


Diagram of a viewers experience in our 'Information Age'.

Within the STEM fields and the visualization of quantitative and analytical data, there is a one-way relationship between the visual that is presented and its viewer; through a reduction of complexity, the viewer passively absorbs information. Through this one-way, reductionist relationship with data, our cognitive engagement deteriorates and we have little understanding of how complex the data actually is as we continue to have little concept of the abstract. Simplified, 2D representations imply that data and its *meaning* are objective truths and are represented objectively without bias. This is false; all data has been touched by human hands, or by a device that we have designed — it has been manipulated, processed, and mapped, whether through algorithms, hardware, or by the collector of the data — sometimes with an outcome already in mind [4]. Within STEM, there is also an assumption that all data must facilitate some sort of disciplinary progress within a specific field, which is also untrue; data can be (and often is) meaningless! The current ruling academic form of data visualization belongs to only a small demographic of people, and has a certain academic focus. It is processed and framed scientifically rather than using the broader critical discourses of aesthetic perception, cognition, and subjectivity [4]. Taking this into account, the reframing of data visualization is highly important to the re-acquisition of skills that allow us to think through complexity. Users can begin to contextualize their individual experience within large abstract data sets, closing the ever widening gap between lived experience and structure [5].

1.1.1 Project Motivation

Tangibility extrudes the usual screen-based representation into the real world, where it can be explored and elicit completely new reactions from the user. Data sculptures are data driven artifacts with a range of flexible constitutive characteristics, but are ultimately made by artists, designers, and scientists who strive to convey meaning and enhance the user's interaction and understanding of the data within its context, while also highlighting unique and inherent complexity [6]. This is why I have chosen to represent a current global issue that is very close to home. I will represent recorded data of Latin American migrants who have been apprehended by United States Border Patrol. I chose this issue because it is an underrepresented contemporary crisis – it is crucial, highly complex, emotional, and heavily debated. Through this emerging medium of communication, I hope to engage the user with social issues.

2. DATA SCULPTURE RESEARCH

As with any interdisciplinary research that I conduct, I begin by identifying the fundamentals. *What is data?* Data is any form of information that is used with a purpose. Information is everything that can be discretely recorded or collected, which is ultimately everything around you. If information is everything then data can also be everything. Representation is depiction with communicative ends. The idea of data as everything helps us think about data representation in an open and creative manner. Data and its representation have few boundaries. Data can be meaningful or pointless, analytical or unsystematic, scientific or cultural. The communicative forms of representation are also broad: verbal, auditory, screen-based, tangible, written, drawn, tasted, smelled, performed, sung, read, etc. Despite all of these different communicative forms, 2D screen-based visualizations are still dominant.

As mentioned in previous sections, I believe we are at a point in our 'Information Age' where information overwhelms and visually over saturates the viewer. The viewer has become numb to both the overload of information and the dominant form in which the information is represented – 2D screen-based visualization. As stated by media theorist Marshall McLuhan,

"...the medium is the message. This is merely to say that the personal and social consequences of any medium – that is, of any extension of ourselves – result from the new scale that is introduced into our affairs by each extension of ourselves, or by any new technology." [7]

According to McLuhan, 2D screen-based visualization is a

medium used to communicate information visually and has become an extension of ourselves over decades of use. After decades of use and experience with this medium we may one day look backward and realize that there were some unanticipated consequences that we were entirely unaware of at the outset [8]. This is not to say that all 2D screen-based visualizations have or will result in negative consequences. There are many cases where 2D screen-based visualizations communicate certain information better than other mediums. However through our current romanticization and monopolization (by technology companies) of new innovation and technology screen-based mediums have been prioritized over alternative mediums of communication, limiting our relationship with both data and technology.

2.1 Benefits of Incorporating Aesthetic Perception: Enabling Cognition

Alternative approaches to the dominant form of data representation include the following: aesthetic perception, cognition, critical thought, and subjectivity. The representation process is the bridge between discrete data and the user's perception [3]. The way in which information is represented directly influences a user's perception and therefor an opinion or judgment on a subject. Naturally, it must be noted that the user already brings their own knowledge and experience to this interaction. Aesthetics can be employed to counteract the reduction of the abstract and instead embrace its complexity by creating a multifaceted experience where the user encounters multiple angles, differing perspectives, and freedom of exploration, ultimately creating a broader understanding of the abstract [9]. Through this, the user applies their cognitive skills to create and then decipher their own interpretation of the data, thus creating one's own perspective on the subject [9]. The user becomes the developer of thought rather than just the consumer. The user is fully engaged with the data, and this engagement can perhaps foster discourse. Aesthetics can also be used to highlight patterns, juxtapose data, and make metaphorical references [10]. As mentioned in previous sections, there is always inherent bias in data. We must acknowledge the inherent bias in every from of representation, and ideally through the use of aesthetics, we can attempt to free the representation of hidden bias [10].

The creation of art can also benefit from real data by creating pieces informed by the material world – especially since contemporary art has gone in the direction of postmodernism, questioning the *real* and thus is highly conceptual. These hybrid pieces simultaneously and congruently become both data representations and works of art. These hybrids can handle complex, emotive, abstract, and analytical subject matter while also being a new and unique medium of communication.

2.2 Physicality Within Aesthetics

Going forward with this conversation, I will be specifically focusing on physicality within aesthetic perception. Physicality can be used to add dimension to representation as well as the sense of touch. With touch, or tangibility, comes functionality, form, space, and affordance. Through the incorporation of functionality there is user interactivity. Affordance is the interaction between a user and an object; by communicating data through a tangible means, affordance emerges [3]. For example, a knob affords twisting, and perhaps pushing, while a cord affords pulling [11] All of these different parameters can be manipulated just like color or texture in order to communicate a different feeling, or insert specific meaning or symbolism into a piece [12]. Each one of these parameters have multiple variables which can be used to map data onto.

In a controlled study done by the Universite Paris-SUD comparing 2D screen-based visualizations with physical representations, the results indicated that the physical representations were more engaging, more user friendly, and more supportive of user exploration leading to deeper understanding of the data [6]. The subjects' fingers were used to mark their place, to rotate, follow paths, and support cognition through the body and physicality [6]. Physicality, specifically, tangibility, played a fundamental role in the user experience of their physical representation in this study.

Although data sculpture is a fairly new and undocumented in comparison to other mediums of communication, researchers such as those at the Universite Paris-SUD, as well as artists, scientists, and designers have begun exploring this new hybrid of art, science, and technology and the potential it may have in perceptual or cognitive exploration, accessibility, further engagement and discourse, as discussed in previous sections.

2.3 Conclusion of the Research

By creating a diagram comparing the relationship between 2D screen-based visualization, a viewer, and the relationship between 3D physical representations and the user, I have emphasized the take away points from my research in data sculpture.

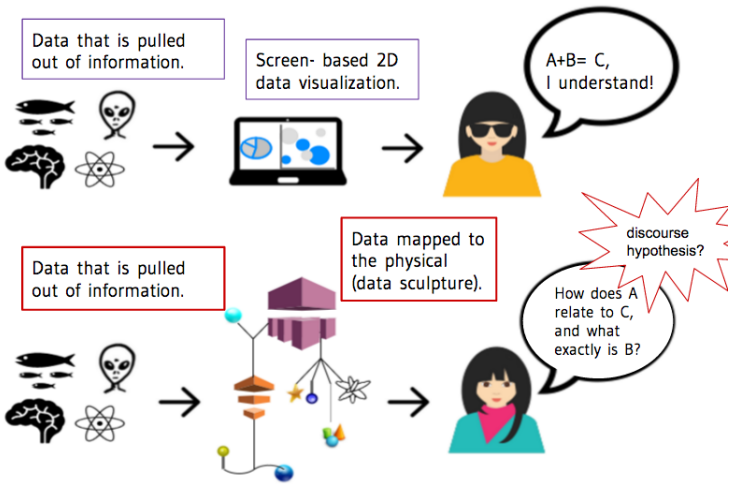


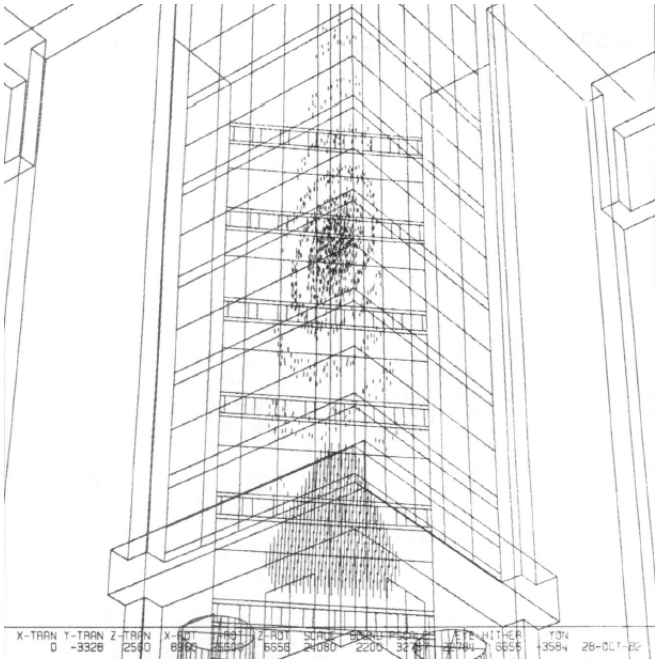
Diagram of two different user experiences with data.

In the figure above you can see the woman on the top easily understands the content communicated to her, and has come out of this interaction with a conclusive answer. Alternatively, the second woman does not come out of the interaction with a conclusive answer. She is physically engaged with the data through all of her senses. Through

this engagement she is thinking critically, asking questions, formulating patterns, making observations, retaining information, and forming ideas on her own. She is engaged with the complexity and uses cognition in order to further her understanding.

3. RELATED WORKS

In this section I will describe a few different contemporary software-aided data sculpture pieces that have informed my own design processes and furthered my understanding of data sculpture as a concept and as a medium.



Galaxy by Robert N. Fisher and Raymond J. Masters (CAD snapshot) [13].

The first piece I will discuss is called *Galaxy*, made in 1983 by Robert N. Fisher and Raymond J. Masters (shown above). Robert and Raymond used imaging data from a computerized simulation of the Milky Way as their material source. They then used computer graphics software and algorithms in order to mathematically map the Milky Way data so that it could be rendered in CAD software [13]. The artists found many benefits to using CAD software for the development of this large environmental sculpture. CAD enabled the artists to observe, rotate, scale, study details, modify proportions and arrangements of elements all in real time with minimal computational effort [13]. One could accurately simulate the sculpture by adding exact data from materials - lines have weight, tubes can bend, objects have mas, etc. as well as add data from the architectural space in order to simulate the exact location of the piece within a space or building. Even though the process of construction was rendered via a computer, the artists felt as though the open nature of the design process was still there - it was even easier for the artists to modify their work and make aesthetic decisions because rendering is made so simple [13].

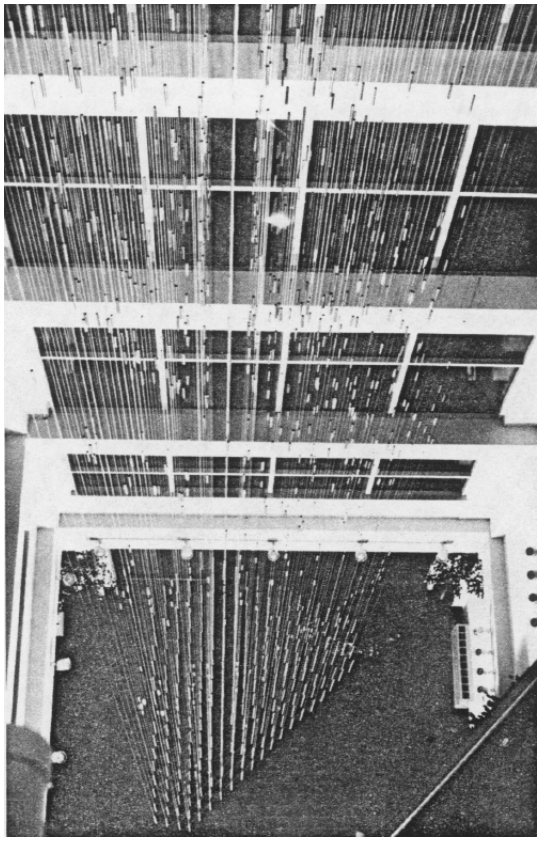


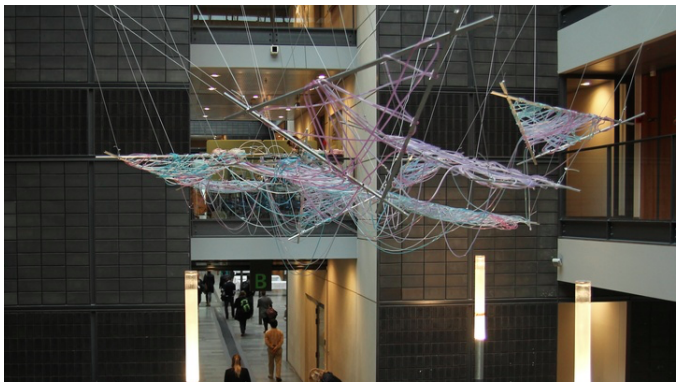
Image of their final installed piece [13].

Through this alternative design processes, the CAD model becomes not only a tool but a symbolic structure that can heighten artistic vision. Having a design idea that inherently lacks materialism is difficult to conceptualize. By using CAD, the artist can bridge the gap from conceptual to material with much more ease and accuracy (in terms of what is envisioned). At a fundamental level, sculpting is creating material from a conceptual and complex idea. Computational power can help bridge the gap from conceptual to material through flexible real time imaging in the many different ways previously discussed.

Touching Air by Stefanie Posavec and Miriam Quick [14].

This next piece is a wearable data sculpture made by Stefanie Posavec and Miriam Quick (shown above). It repre-

sents a week's worth of data from sensors measuring large particulate levels. Each segment represents six hours measured during the week. The segments range in color, where the cleaner air is represented in light blue, and the more dangerous air quality measurements are represented in red. The segments also range in size from small to large and in texture from completely smooth to spiky and sharp to touch; the larger and spikier the segment, the more particulates in the air at that time. By running their fingers over the piece, the wearer can physically feel how the air quality in Sheffield, UK went up and down over the course of a week. Hazardous particulate levels have the potential to prick the finger of the wearer [14].



Chaotic Flow by Tobias Lukassen, Halfdan Hauch Jensen and Johan Bichel Lindegaard [15].

This last example is a data sculpture designed by Tobias Lukassen, Halfdan Hauch Jensen and Johan Bichel Lindegaard (shown above). It is physical hanging piece made up of 1000 meters of PVC tubing, and was installed in Copenhagen's municipality building. It was created and installed for a conference on urban planning. With data given to them by the municipality, the artists represent how many bikes pass through specific streets of Copenhagen every hour throughout the day. These artists used computational tools such as python, C++ with open-frameworks, and arduino micro-controllers to convert the statistical cyclist data into an abstract simulation of the city's flow. Through the use of these computational tools Copenhagen's bicycle traffic was represented by using pumps and compressed air to push colored water through the clear PVC tubing in a continuous flowing manner [15].

These three different pieces give us an example of quantitative information being transformed into a data sculpture. The artists were able to turn the very abstract subject of their data into a sculpture that transcends media – the technology becomes ubiquitous. Instead of glorifying the use and consumption of media or technology, the artist's only used it as a tool in order to create their piece. This highlights technology as a functional tool rather than a novel commodity to be consumed. These pieces also juxtapose the numerical and discrete data that was used to model the sculpture with the ambient sensory aesthetics executed in their final pieces. This unique medium of representation does not focus on analytical or quantitative understanding of information but instead values the deep thinking of the abstract through aesthetics and physical materials.

4. DESIGNING A DATA SCULPTURE

In the following section I will be elaborating on the design processes of my own attempt at a data sculpture. I hope others interested in data sculpture and other alternative mediums of communication will find this section informative and perhaps even inspiring. I will describe my reasoning behind choosing to represent Latin American migrant data. I will give an explanation of how I mapped the data on to the physical, as well as a break down of the hardware and software used and their place within the design model.

4.1 Data

Being the daughter of a Nicaraguan immigrant, and being a Latin American immigrant myself, I have been immersed in the issue of Latin American migration my entire life. I have heard incredible stories told by friends and family describing their journey to the United States. Stories of 8-month pregnant mothers crossing the Rio Grande so that their child could have U.S. citizenry, and of families being torn apart because of the United States federal laws on illegal migration. I find these stories to be more powerful than the statistical and scientific data visualized on graphs and charts provided by many mainstream news sources. Through the implementation of a data sculpture, I hope to represent, as best as I can, the journey of struggle and pain faced by migrants who risk their lives crossing the border and who face oppression in the United States. I do not want to reduce the complexity of the issue for easier comprehension, but instead embrace the complexity of the issue. Even though apprehensions do not account for those who make it through to the U.S. or those who don't make it through for various reasons, apprehensions still shed light on important migration patterns over time. For example, who is migrating, when they are migrating, their age, place of origin, and crossing location.

The Latin American migrant data I used primarily came from the U.S. Customs and Border Protection database. The following image is a snapshot of the data after it was aggregated and then inserted into my own database. The database system used is an open source object-relational database system called PostgreSQL.

```
sadie_db=> \d central_am_deport
      Table "public.central_am_deport"
  Column   |          Type          | Modifiers
-----------+------------------------+-----------
 sector    | character varying(20) |
 year_2000 | integer                |
 year_2001 | integer                |
 year_2002 | integer                |
 year_2003 | integer                |
 year_2004 | integer                |
 year_2005 | integer                |
 year_2006 | integer                |
 year_2007 | integer                |
 year_2008 | integer                |
 year_2009 | integer                |
 year_2010 | integer                |
 year_2011 | integer                |
 year_2012 | integer                |
 year_2013 | integer                |
 year_2014 | integer                |

sadie_db=> \d mexican_deport
      Table "public.mexican_deport"
  Column   |          Type          | Modifiers
-----------+------------------------+-----------
 sector    | character varying(20) |
 year_2000 | integer                |
 year_2001 | integer                |
 year_2002 | integer                |
 year_2003 | integer                |
 year_2004 | integer                |
 year_2005 | integer                |
 year_2006 | integer                |
 year_2007 | integer                |
 year_2008 | integer                |
 year_2009 | integer                |
 year_2010 | integer                |
 year_2011 | integer                |
 year_2012 | integer                |
 year_2013 | integer                |
 year_2014 | integer                |
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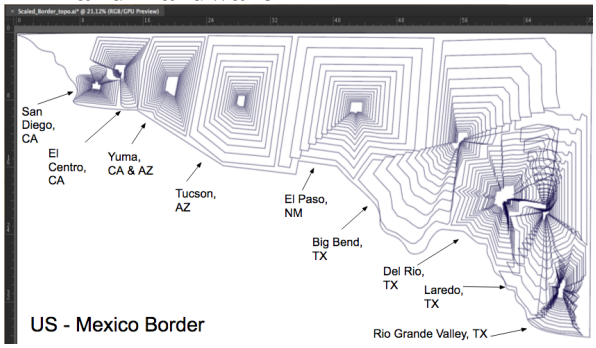
Data tables in PostgreSQL database.

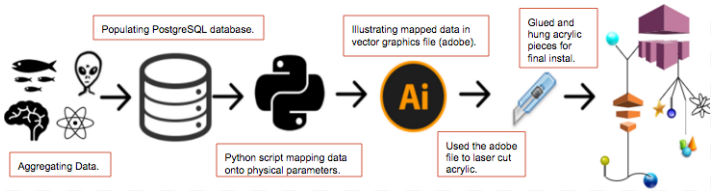
4.2 Mapping Data onto the Physical: Software and Hardware



Vector graphics scaling file.

Each column represents a border sector. Each row represents the years between 2011 (top row) and 2014. The clear layers represent apprehended Mexicans, and the colored layers represent apprehended Central Americans (El salvador, Honduras, and Guatemala). As seen in the vector graphics adobe illustrator file above, each sector initially begins the implementation process with 16 layers. The largest (or first) layer represents 100,000 Latin American apprehensions, the second layer represents 80,000, the third 60,000 etc. Through PostgreSQL I queried a specific year, sector, and place of origin from my Latin American migrant apprehension database. I then inputted this number into a python dictionary that simply told me what (out of the 16) scaled layers I needed to laser cut in order to accurately represent the selected data. The cool tones (purple, blue, green) represent the sectors that are along either the Rio Grande or Rio Bravo. The warm tones (yellow, orange, pink) represent the sectors that are primarily desert.

The following diagram is of my implementation work-flow where one can see the use of many different computational components in the creation of my data sculpture.



Implemented work-flow.

Final installed data sculpture representing Latin American migrant apprehensions from the SW U.S. border sectors during the years 2011-2014.

5. CONCLUSION

Anything that can be experienced can also be data. Love affairs, revolutions, dreams, rainbows, death, and tables; all can be reduced to their constituent parts and represented as figures. To represent data is to represent reality, and there is no reason that these representations should be restricted to a particular limited mode of expression. With the widespread onset of digital communications technologies, our data visualizations (and by extension, our models and *understanding* of reality) have become increasingly standardized. Complexity has been exchanged for simplification in the form of info-graphics, pie charts, regressions, and bar graphs. The physicality, ambiguity, and complexity of data sculpture allows us to fundamentally re-imagine data representation, and by extension, our perception of data (reality). I have created this data sculpture in an effort to gesture towards an alternative form of expression that more accurately captures the complex totality of a facet of existence. It is my hope that the piece will encourage viewers to adopt a more critical relationship to their consumption of digitally-communicated information, and inspire others to consider expressing their ideas and observations in a way that more accurately captures the totality of our collective realities, and sensory experiences.

6. ACKNOWLEDGMENTS

I would like to thank all of those who helped me in the exploration of the concept of data sculpture, as well as the creation and installation of my final piece. Xunfei Jiang, Charlie Peck, Jose Ignacio, Barbara Miller, Ian Smith (and all of those who work in Earlham Colleges facilities), Bobbie Cayard-Roberts, Lara Miller, Tara Urner, Kristin Muterspaw, George Crowson, and Craig Earley.

Thank you.

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