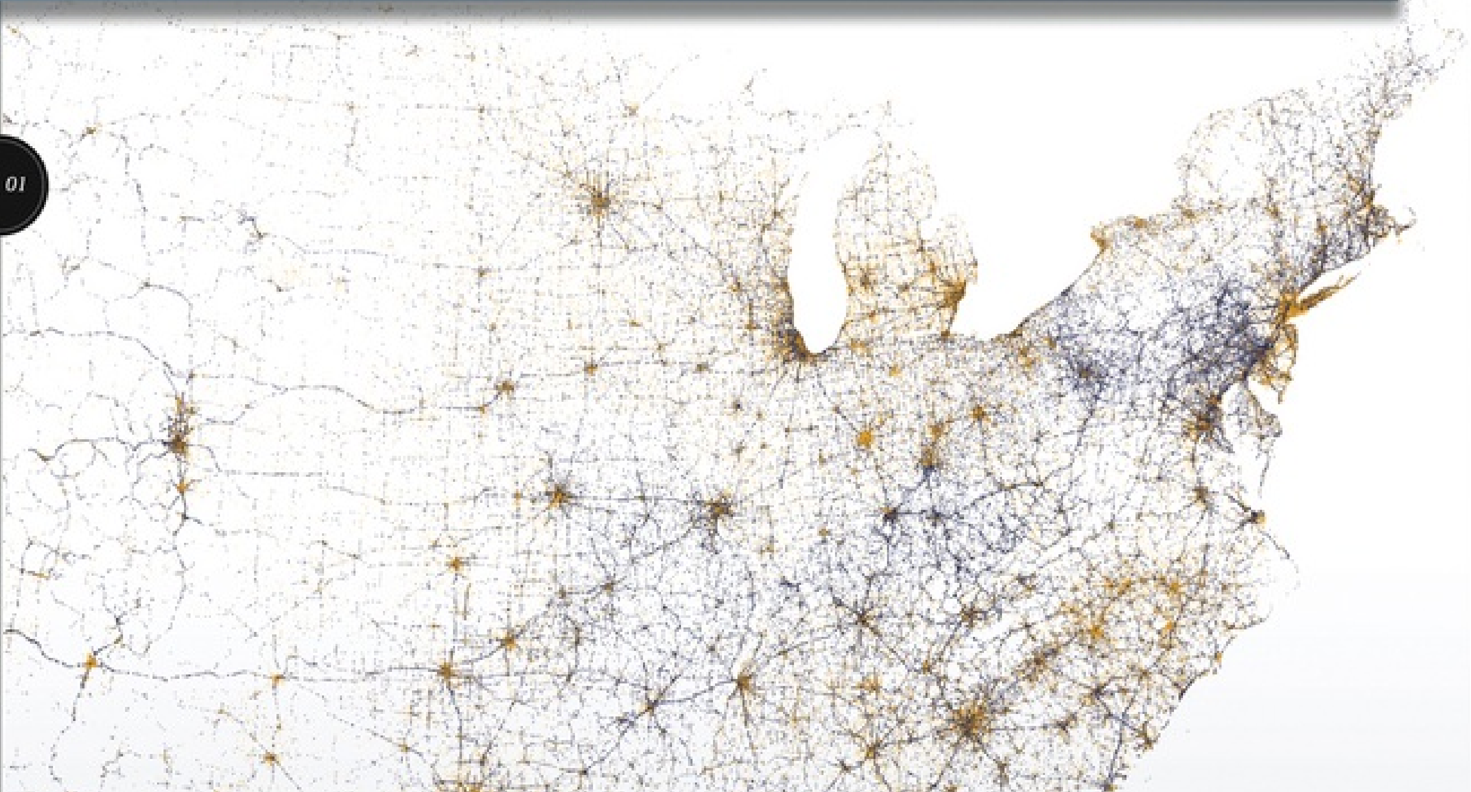
AUTHOR **NATHAN YAU**

DATA POINTS

VISUALIZATION THAT MEANS SOMETHING

Ex. 01



WILEY

FLOWINGDATA.COM

Table of Contents

Introduction

What is good visualization? It is a representation of data that helps you see what you otherwise would have been blind to if you looked only at the naked source. It enables you to see trends, patterns, and outliers that tell you about yourself and what surrounds you. The best visualization evokes that moment of bliss when seeing something for the first time, knowing that what you see has been right in front of you, just slightly hidden. Sometimes it is a simple bar graph, and other times the visualization is complex because the data requires it.

The Process

A data set is a snapshot in time that captures something that moves and changes. Collectively, data points form aggregates and statistical summaries that can tell you what to expect. These are your means, medians, and standard deviations. They describe the world, countries, and populations and enable you to compare and contrast things. When you push down on the data, you get details about the individuals and objects within the population. These are the stories that make a data set human and relatable.

Data in an abstract sense that includes information and facts is the foundation of every visualization. The more you understand about the source and the stronger base that you build, the greater the potential for a compelling data graphic. This is the part that a lot of people miss: Good visualization is a winding process that requires statistics and design knowledge. Without the former, the visualization becomes an exercise only in illustration and aesthetics, and without the latter, one of only analyses. On their own, these are fine skills, but they make for incomplete data graphics. Having skills in both provides you with the luxury—which is growing into a necessity—to jump back and forth between data exploration and storytelling.

This book is for those interested in the process of design and analysis, where each chapter represents a step toward visualization that means something. It is about visualization that is more than large printed numbers with clipart. It is about making sense of data. Visualization creation is iterative, and the cycle is always a little different for each new dataset.

The first part of *Data Points* helps you know your data and what it means to visualize it. Because of what data represents—people, places, and things—there is always important context attached to the factual numbers. Who is the data about? Where is the data from? When was it collected? We are responsible for this human part of the computer-generated output, too. On top of that, most datasets are estimated, so they are not the absolute truth; there is uncertainty and variability attached, just like in real life.

In the middle of the book, you go into exploration mode. You have the freedom to ask questions and try to answer them by digging through the data. Look for patterns, relationships, and anything that does not look right. Missing values are common, as are typos. This is a great time to play and experiment, to look around from different angles, and maybe you'll find something unexpected. Maybe that bit ends up being the most interesting part of the story. For whatever reason, the exploration stage is skipped too often, and lack of understanding shows in the final product. Take the time to get to know your data and what it represents, and the visualization improves exponentially.

When you find the underlying narratives, the next step is typically to communicate your results to a wider audience.

This is the last section, when you put your design hat on. A graphic for a small audience of four people who are familiar with the subject matter and have read every significant paper on the topic will be different than a graphic for a large, general audience unfamiliar with the complex background implied by the numbers.

Again, these stages are not meant as a step-by-step guide. If you work with data already, you know that it is common to discover a need for new data as you explore what you already have. Similarly, the design process can force you to see details that you didn’t notice before, which takes you back to exploration or to the beginning. If you are new to data, you must learn this process while reading this book to feel confident enough to use it in your own projects. The back and forth between data and story is the fun stuff.

Data Points is a complement tomy previous book *Visualize This*. The first book serves as an introduction to the tools available and offers concrete programming examples, whereas this book describes the full process and thinking that goes into larger data projects and is software-independent. In other words, the two books feed off each other. *Visualize This* provides technical guidance for those ready to make their own graphics, and *Data Points* describes a process for data and visualization so that you can create better and more thoughtful things.

More Than a Tool

Throughout this book, visualization is referred to as a medium rather than a specific tool. When you approach visualization as an unyielding tool, it is easy to get caught thinking that almost every graphic would be better as a bar graph. This is true for a lot of charts, but it must be in the right context. In an analysis setting, yes, you often want graphs that read the quickest and most accurately;

however, from another point of view, such a comment might be premature. What if emotion and curiosity are the goals? Visualization is a way to represent data, an abstraction of the real world, in the same way that the written word can be used to tell different kinds of stories. Newspaper articles aren't judged on the same criteria as novels, and data art should be critiqued differently than a business dashboard.

That said, there are rules to follow regardless of the visualization type. These aren't dictated by design or statistics. Rather they are governed by human perception, and they ensure accuracy when readers interpret encoded data. There are only a handful of these, such as to properly size by area when that aspect is the actual visual cue, and all the rest are suggestions.

You must distinguish between rules and suggestions. You should follow the former almost always, whereas suggestions are rooted in opinion and vary among individuals and situations. Many beginners make the mistake that advice is concrete, and they lose the context in which the data is presented in. For example, Edward Tufte suggests stripping charts of all junk, but the definition of junk can change. What needs to be stripped from one chart might need to stay in another. In the words of Tufte, "Most principles of design should be greeted with some skepticism."

Similarly, people often cite the work of statisticians William Cleveland and Robert McGill on perception and accuracy. They found that position along a common scale, such as with a scatterplot, was decoded most accurately, followed by length, angle, and then slope. These results are based on research trials and were reproduced in other studies, so it is easy to mistake Cleveland and McGill's findings as rules. However, Cleveland also notes that the mark of a good graph is not only how fast you can read it, but also what it shows. Does it enable you to see what you could not see before?

You must come back to the data for worthwhile visualization. Fortunately, you have plenty of data to play with, and the source keeps growing. Every week for the past few years, there is an article that describes the flood of data and the risk of drowning in it, but you see, the amount is controlled, and you can easily filter and aggregate it. Storage is cheap and practically infinite, which means more potential happy feelings for those who know how to swim. The challenge is learning to dive deeper.

Okay, I’m psyched. Let’s have some fun.

Chapter 1

Understanding Data

When you ask people what data is, most reply with a vague description of something that resembles a spreadsheet or a bucket of numbers. The more technically savvy might mention databases or warehouses. However, this is just the format that the data comes in and how it is stored, and it doesn’t say anything about what data is or what any particular dataset represents. It’s an easy trap to fall in because when you ask for data, you usually get a computer file, and it’s hard to think of computer output as anything but just that. Look beyond the file though, and you get something more meaningful.

What Data Represents

Data is more than numbers, and to visualize it, you must know what it represents. Data represents real life. It’s a snapshot of the world in the same way that a photograph captures a small moment in time.

Figure 1-1: A single photo, a single data point

Look at Figure 1-1. If you were to come across this photo, isolated from everything else, and I told you nothing about it, you wouldn’t get much out of it. It’s just another wedding photo. For me though, it’s a happy moment during one of the best days of my life. That’s my wife on the left, all dolled up, and me on the right, wearing something other than jeans and a T-shirt for a change. The pastor who is marrying us is my wife’s uncle, who added a personal touch to the ceremony, and the guy in the back is a family friend who took it upon himself to record as much as possible, even though we hired a photographer. The flowers and archway came from a local florist about an hour away from the venue, and the wedding took place during early summer in Los Angeles, California.

That’s a lot of information from just one picture, and it works the same with data. (For some, me included, pictures are data, too.) A single data point can have a who, what, when, where, and why attached to it, so it’s easy for a digit to become more than a toss in a bucket. Extracting information from a data point isn’t as easy as looking at a photo, though. You can guess what’s going on in the photo, but when you make assumptions about data, such as how accurate it is or how it relates to its surroundings, you can end up with a skewed view of what your data actually represents. You need to look at everything around, find context, and see what your dataset looks like as a whole. When you see the full picture, it’s much easier to make better judgments about individual points.

Imagine that I didn’t tell you those things about my wedding photo. How could you find out more? What if you could see pictures that were taken before and after?

Now you have more than just a moment in time. You have several moments, and together they represent the part of the wedding when my wife first walked out, the vows, and the tea drinking ceremony with the parents and my grandma, which is customary for Chinese weddings. Like the first photo, each of these has its own story, such as my father-in-law welling up as he gave away his daughter or how happy I felt when I walked down the aisle with my bride. Many of the photos captured moments that I didn’t see from my point of view during the wedding, so I almost feel like an outsider looking in, which is probably how you feel. But the more I tell you about that day, the less obscure each point becomes.

Still though, these are snapshots, and you don’t know what happened in between each photo. (Although you could guess.) For the complete story, you’d either need to be there or watch a video. Even with that, you’d still see only the ceremony from a certain number of angles because it’s often not feasible to record every single thing. For example, there was about five minutes of confusion during the ceremony when we tried to light a candle but the wind kept blowing it out. We eventually ran out of matches, and the wedding planner went on a scramble to find something, but luckily one of our guests was a smoker, so he busted out his lighter. This set of photos doesn’t capture that, though, because again, it’s an abstraction of the real thing.

This is where sampling comes in. It’s often not possible to count or record everything because of cost or lack of manpower (or both), so you take bits and pieces, and then you look for patterns and connections to make an educated guess about what your data represents. The data is a simplification—an abstraction—of the real world. So when you visualize data, you visualize an abstraction of the world, or at least some tiny facet of it. Visualization is an abstraction of data, so in the end, you end up with an abstraction of an abstraction, which creates an interesting challenge.

However, this is not to say that visualization obscures your view—far from it. Visualization can help detach your focus from the individual data points and explore them from a different angle—to see the forest for the trees, so to speak. To keep running with this wedding photo example, Figure 1-3 uses the full wedding dataset, of which Figure 1-1 and Figure 1-2 were subsets of. Each rectangle represents a photo from our wedding album, and they are colored by the most common shade in each photo and organized by time.

Figure 1-2: Grid of photos

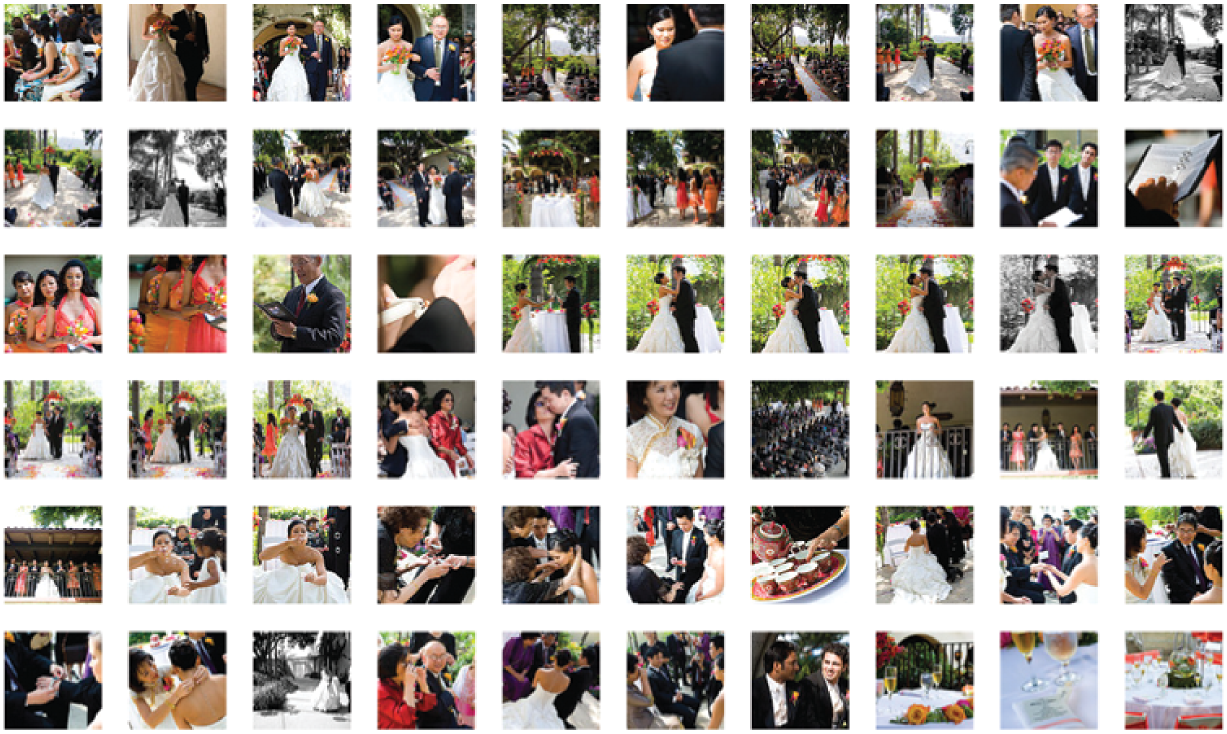
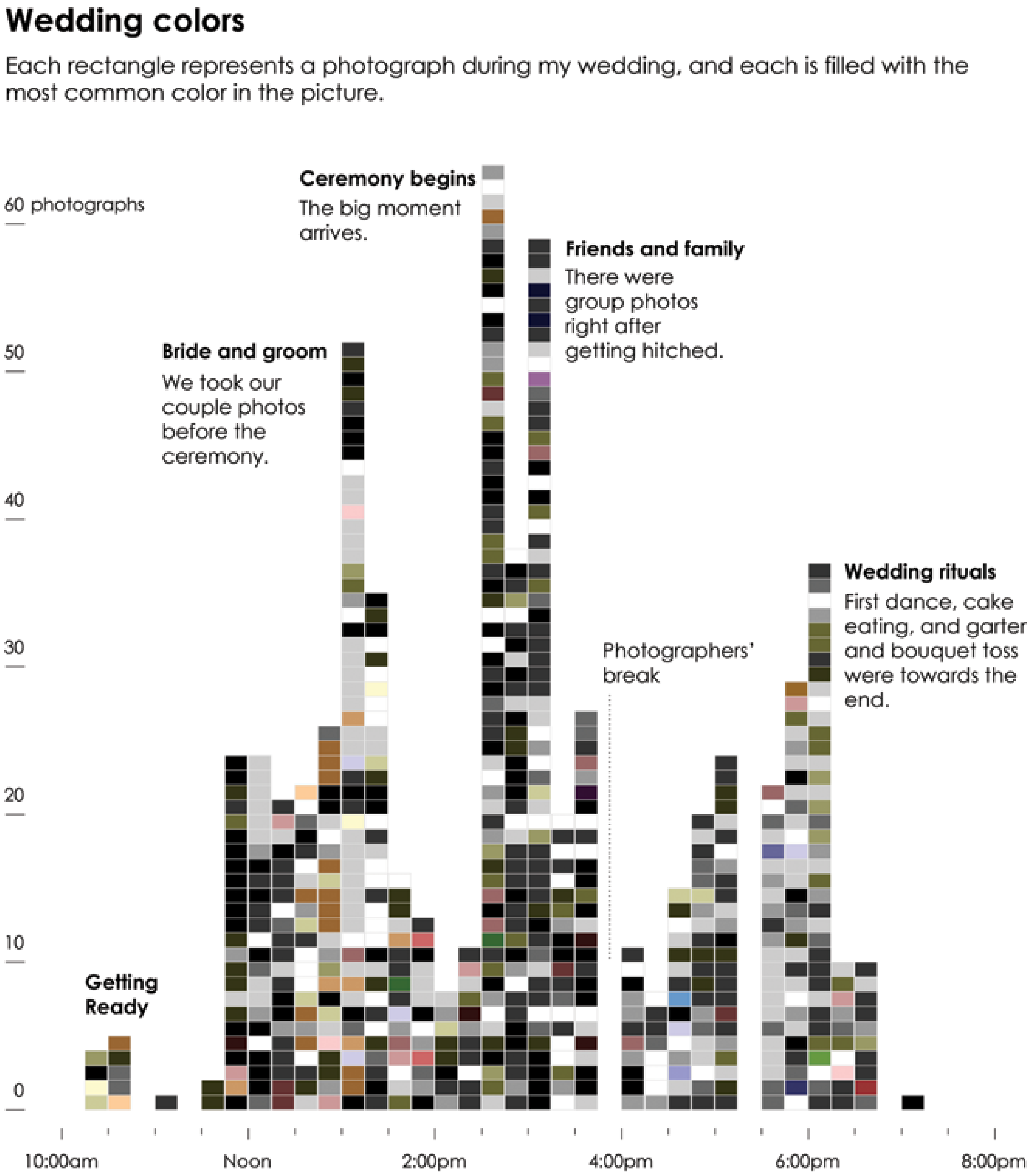


Figure 1-3: Colors in the wedding



Wedding colors

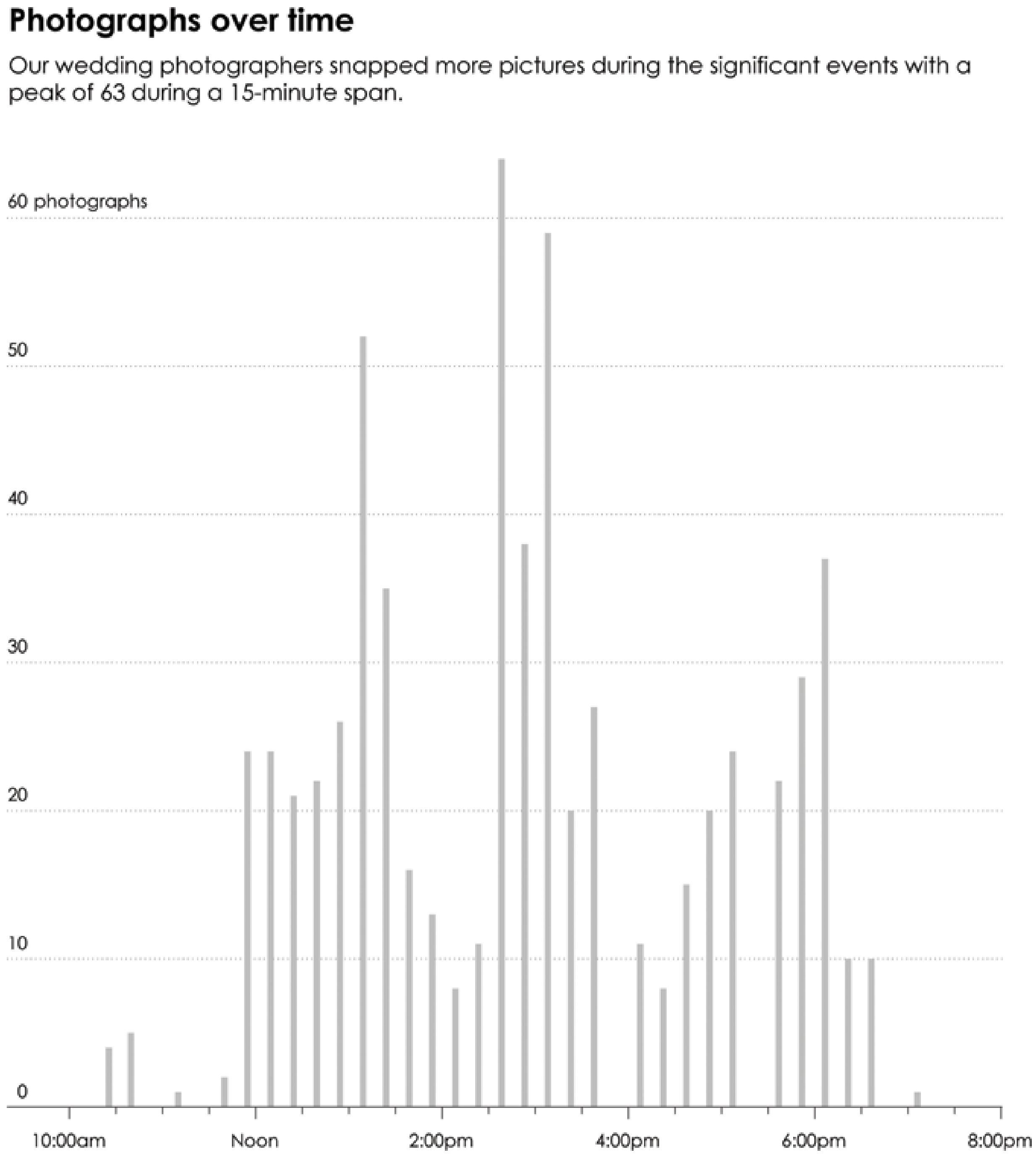
Each rectangle represents a photograph during my wedding, and each is filled with the most common color in the picture.

With a time series layout, you can see the high points of the wedding, when our photographers snapped more shots, and the lulls, when only a few photos were taken. The peaks in the chart, of course, occur when there is something to take pictures of, such as when I first saw my wife in her dress or when the ceremony began. After the ceremony, we took the usual group photos with friends and family, so there was another spike at that point. Then there was food, and activity died down, especially when the photographers took a break a little before 4 o’clock. Things picked up again with typical wedding fanfare, and the day came to an end around 7 in the evening. My wife and I rode off into the sunset.

In the grid layout, you might not see this pattern because of the linear presentation. Everything seems to happen with equal spacing, when actually most pictures were taken during the exciting parts. You also get a sense of the colors in the wedding at a glance: black for the suits, white for the wedding dress, coral for the flowers and bridesmaids, and green for the trees surrounding the outdoor wedding and reception. Do you get the detail that you would from the actual photos? No. But sometimes that level isn’t necessary at first. Sometimes you need to see the overall patterns before you zoom in on the details. Sometimes, you don’t know that a single data point is worth a look until you see everything else and how it relates to the population.

You don’t need to stop here, though. Zoom out another level to focus only on the picture-taking volumes, and disregard the colors and individual photos, as shown in Figure 1-4.

Figure 1-4: Photos over time



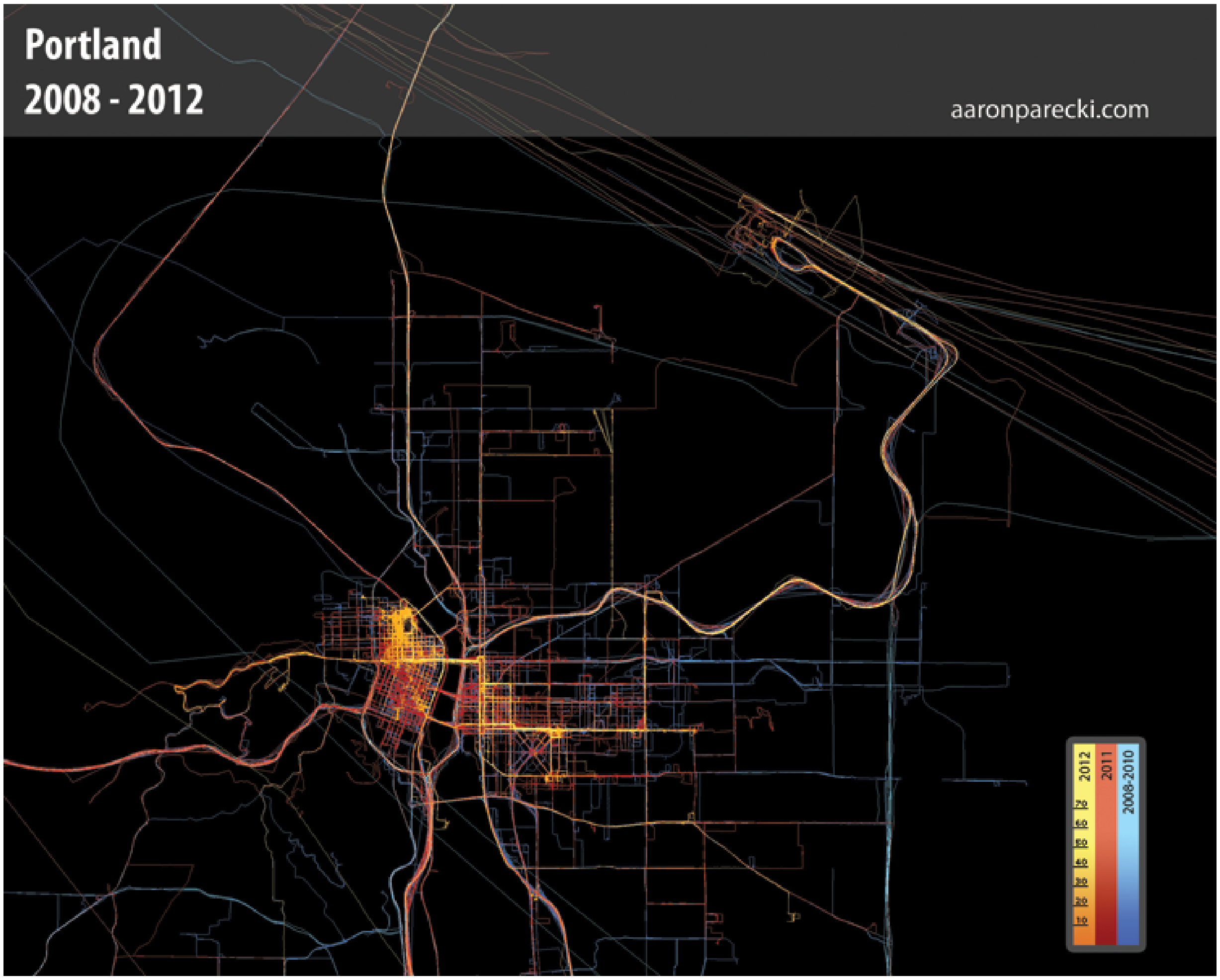
You’ve probably seen this layout before. It’s a bar chart that shows the same highs and lows as in Figure 1-3, but it has a different feel and provides a different message. The simple bar chart emphasizes picture-taking volumes over time via 15-minute windows, whereas Figure 1-3 still carries some of the photo album’s sentiment.

The main thing to note is that all four of these views show the same data, or rather, they all represent my wedding day. Each graphic just represents the day differently, focusing on various facets of the wedding. Interpretation of the data changes based on the visual form it takes on. With traditional data, you typically examine and explore from the bar chart side of the spectrum, but that doesn’t mean you have to lose the sentiment of the individual data point—that single photo. Sometimes that means adding meaningful annotation that enables readers to interpret the data better, and other times the message in the numbers is clear, gleaned from the visualization itself.

The connection between data and what it represents is key to visualization that means something. It is key to thoughtful data analysis. It is key to a deeper understanding of your data. Computers do a bulk of the work to turn numbers into shapes and colors, but you must make the connection between data and real life, so that you or the people you make graphics for extract something of value.

This connection is sometimes hard to see when you look at data on a large scale for thousands of strangers, but it’s more obvious when you look at data for an individual. You can almost relate to that person, even if you’ve never met him or her. For example, Portland-based developer Aaron Parecki used his phone to collect 2.5 million GPS points over 31/2 years between 2008 and 2012, about one point every 2 to 6 seconds. Figure 1-5 is a map of these points, colored by year.

Figure 1-5: GPS traces collected by Aaron Parecki, http://aaronparecki.com

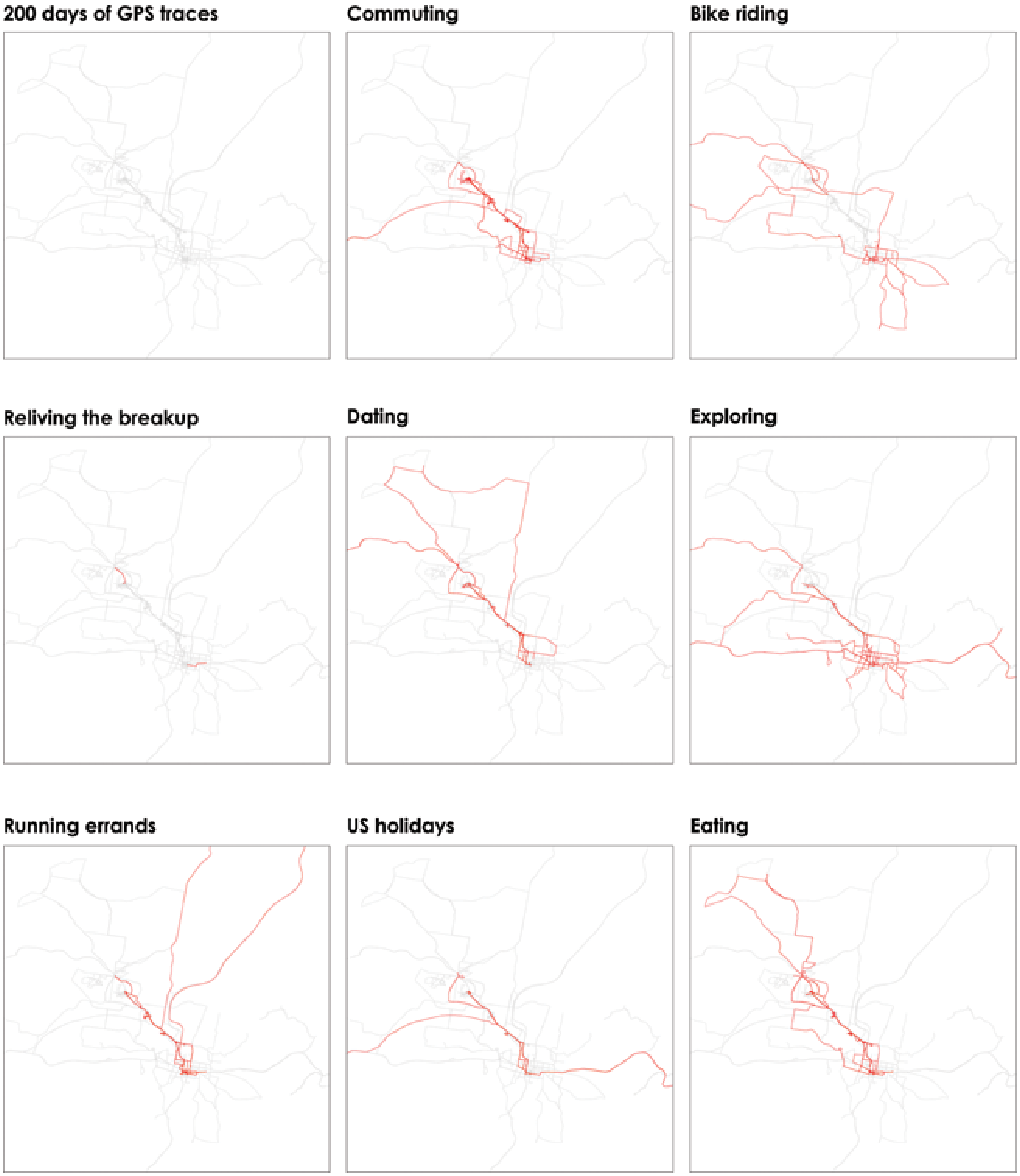


As you’d expect, the map shows a grid of roads and areas where Parecki frequented that are colored more brightly than others. His housing changed a few times, and you can see his travel patterns change over the years. Between 2008 and 2010, shown in blue, travel appears more dispersed, and by 2012, in yellow, Parecki seems to stay in a couple of tighter pockets. Without more context it is hard to say anything more because all you see is location, but to Parecki the data is more personal (like the single wedding photo is to me). It’s the footprint of more than 3 years in a city, and because he has access to the raw logs, which have time attached to them, he could also make better decisions based on data, like when he should leave for work.

What if there were more information attached to personal time and location data, though? What if along with where you were, you also took notes during or after about what was going on at some given time? This is what artist Tim Clark did between 2010 and 2011 for his project *Atlas of the Habitual*. Like Parecki, Clark recorded his location for 200 days with a GPS-enabled device, which spanned approximately 2,000 miles in Bennington, Vermont. Clark then looked back on his location data and labeled specific trips, people he spent time with, and broke it down by time of year.

As shown in Figure 1-6, the atlas, with clickable categorizations and time frames, shows a 200-day footprint that reads like a personal journal. Select “Running errands” and the note reads, “Doing the everyday things from running to the grocery store all the way to driving 30 miles to the only bike shop in southern Vermont opened on Sundays.” The traces stay around town, with the exception of two long ones that venture out.

Figure 1-6: Selected maps from Atlas of the Habitual by Tim Clark, http://www.tlclark.com/atlasofthehabitual/

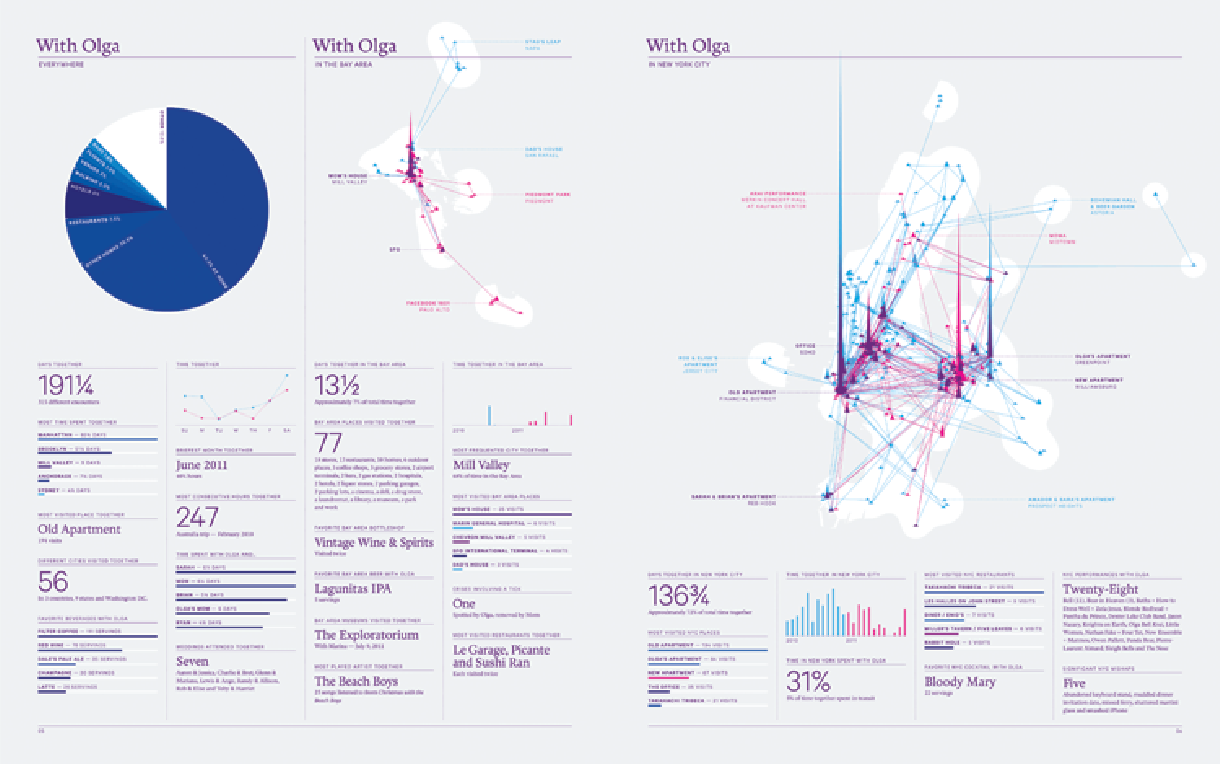


There is one entry titled “Reliving the breakup,” and Clark writes, “A long-term girlfriend and I broke up immediately before I moved. These are the times that I had a real difficult time coming to terms that I had to move on.” Two small paths, one within the city limits and one outside, appear, and the data suddenly feels incredibly personal.

This is perhaps the appeal behind the Quantified Self movement, which aims to incorporate technology to collect data about one’s own activity and habits. Some people track their weight, what they eat and drink, and when they go to bed; their goal is usually to live healthier and longer. Others track a wider variety of metrics purely as a way to look in on themselves beyond what they see in the mirror; personal data collection becomes something like a journal for self-reflection at the end of the day.

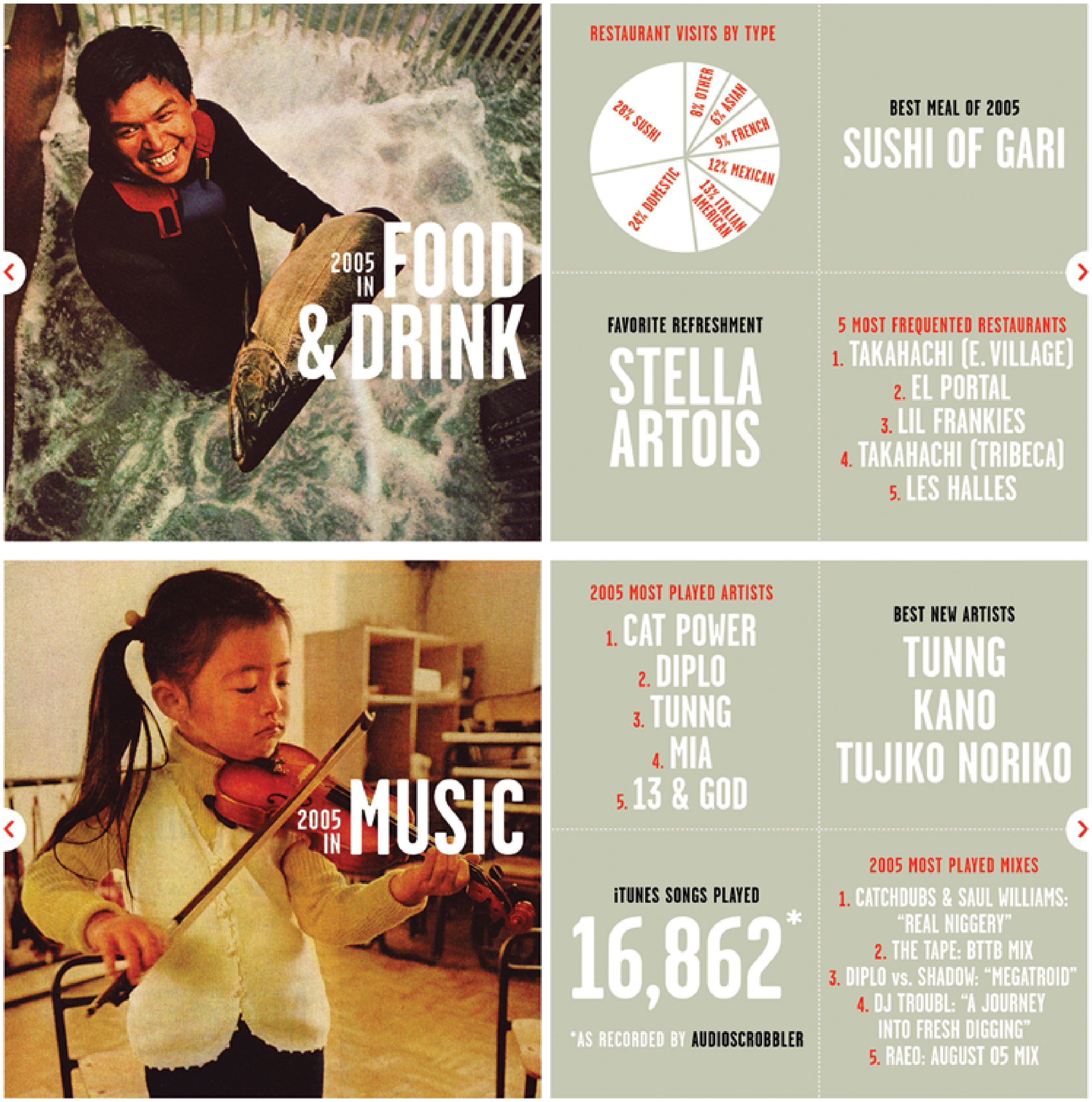
Nicholas Felton is one of the more well-known people in this area for his annual reports on himself, which highlight both his design skills and disciplined personal data collection. He keeps track of not just his location, but also who he spends time with, restaurants he eats at, movies he watches, books he reads, and an array of other things that he reveals each year. Figure 1-7 is a page out of Felton’s 2010/2011 report.

Figure 1-7: A page from 2010/2011 Annual Report by Nicholas Felton, http://feltron.com



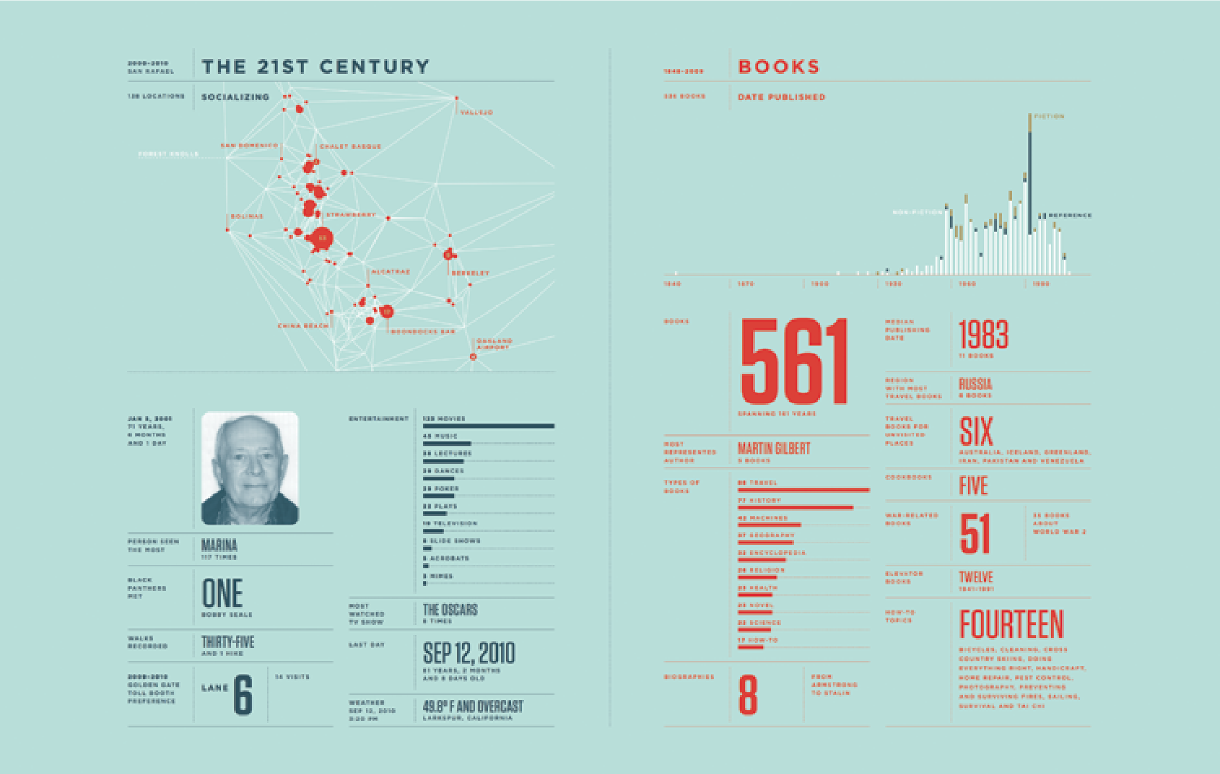
Felton designed his first annual report in 2005 and has done one every year since. Individually, they are beautiful to look at and hold and satisfy an odd craving for looking in on a stranger’s life. What I find most interesting, though, is the evolution of his reports into something personal and the expanding richness of data. Looking at his first report, as shown in Figure 1-8, you notice that it feels a lot like a design exercise in which there are touches of Felton’s personality embedded, but it is for the most part strictly about the numbers. Each year though, the data feels less like a report and more like a diary.

Figure 1-8: Selected pages from 2005 Annual Report by Nicholas Felton, http://feltron.com



This is most obvious in the *2010 Annual Report*. Felton's father passed away at the age of 81. Instead of summarizing his own year, Felton designed an annual report, as shown in Figure 1-9, that cataloged his father's life, based on calendars, slides, postcards, and other personal items. Again, although the person of focus might be a stranger, it's easy to find sentiment in the numbers.

Figure 1-9: Selected pages from 2010 Annual Report by Nicholas Felton, http://feltron.com



When you see work like this, it's easy to understand the value of personal data to an individual, and maybe, just maybe, it's not so crazy to collect tidbits about yourself. The data might not be useful to you right away, but it could be a decade from now, in the same way it's useful to stumble upon an old diary from when you were just a young one. There's value in remembering. In many ways you log bits of your life already if you use social sites like Twitter, Facebook, and foursquare. A status update or a tweet is like a mini-snapshot of what you're doing at any given moment; a shared photo with a timestamp can mean a lot decades from now; and a check-in firmly places your digital bits in the physical world.

You've seen how that data can be valuable to an individual. What if you look at the data from many individuals in aggregate?

The United States Census Bureau collects the official counts of people living in the country every 10 years. The data is a valuable resource to help officials allocate funds, and from census to census, the fluctuations in population help you see how people move in the country, changing the neighborhood composition, and how areas grow and shrink. In short, the data paints a picture of who lives in America. However, the data, collected and maintained by the government, can show only so much about the individuals, and it’s hard to grasp who the people actually are.

What are their likes and dislikes? What kind of personality do they have? Are there major differences between neighboring cities and towns?

Media artist Roger Luke DuBois took a different kind of census, via 19 million online dating profiles in *A More Perfect Union*. When you join an online dating site, you first describe yourself: who you are, where you’re from, and what you’re interested in. After you uncomfortably fill out that information, and perhaps choose not to share a thing or two, you describe what your ideal mate is like. In the words of DuBois, in the latter, you tell the complete truth, and in the former, you lie. So when you aggregate people’s online dating profiles, you get some combination of how people see themselves and how they want to be seen.

In *A More Perfect Union*, DuBois categorized online dating profiles, digital encapsulations of hopes and dreams, by postal code, and then looked for the word that was most unique to each area. Using a tracing of a Rand McNally map, DuBois replaced each city name with the city’s unique word and painted a different picture of the United States: a more recognizable and personal one.

In Figure 1-10, around southern California, where they make the talkies, words such as *acting*, *writer*, and *entertainment* appear; on the other hand, in Washington, DC, shown in Figure 1-11, words like *bureaucrat*, *partisan*, and *democratic* appear. These mostly pertain to professions, but in some areas the words describe personal attributes, favorite things, and major events.

Figure 1-10: California map from A More Perfect Union (2011) by R. Luke DuBois, courtesy of the artist and bitforms gallery, New York City, http://perfect.lukedubois.com

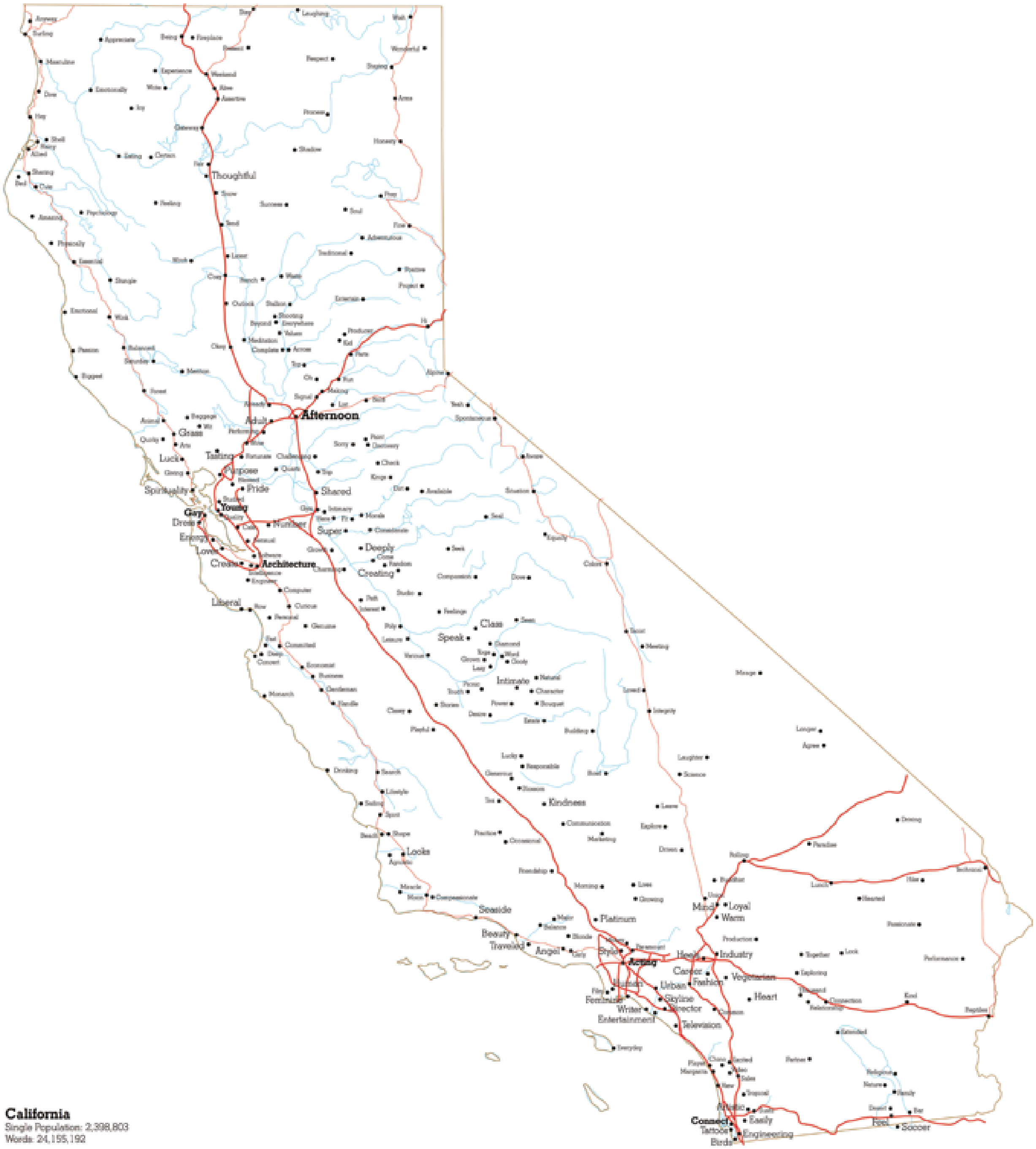
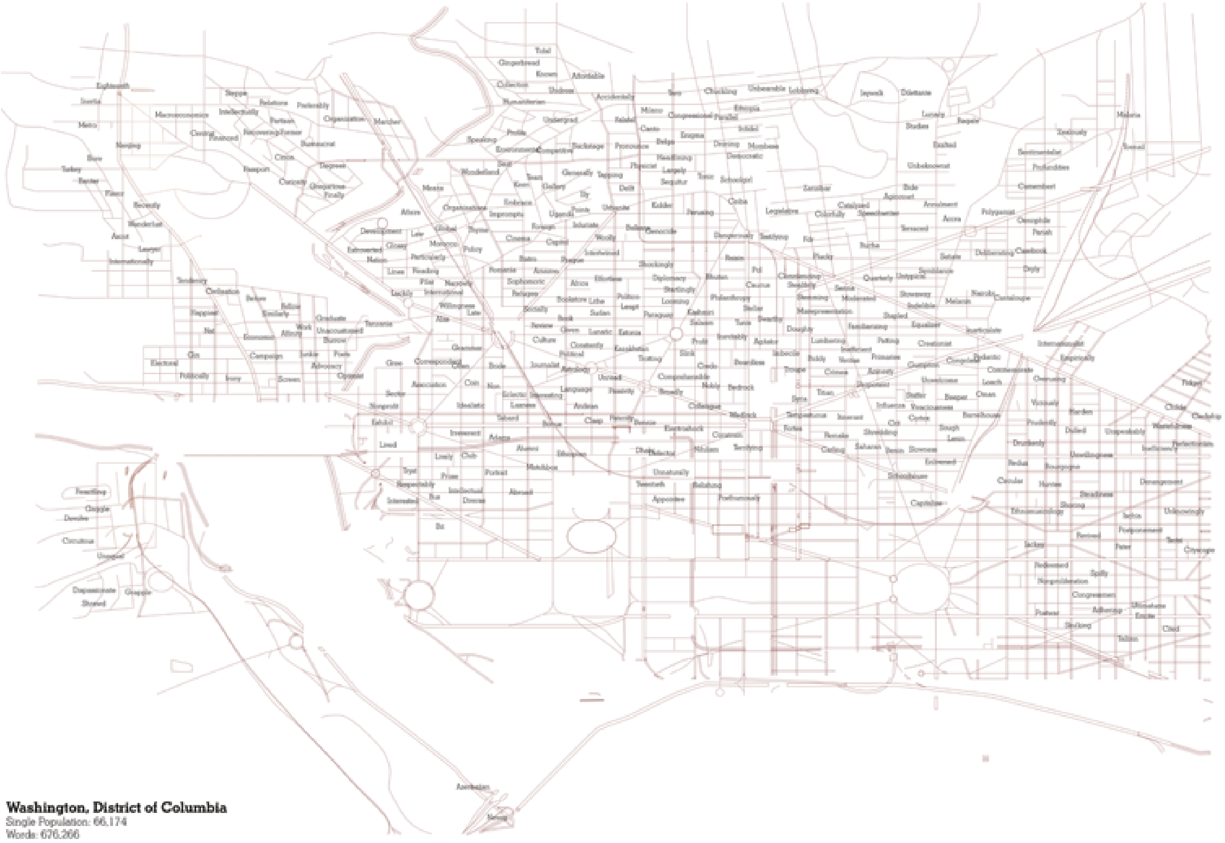
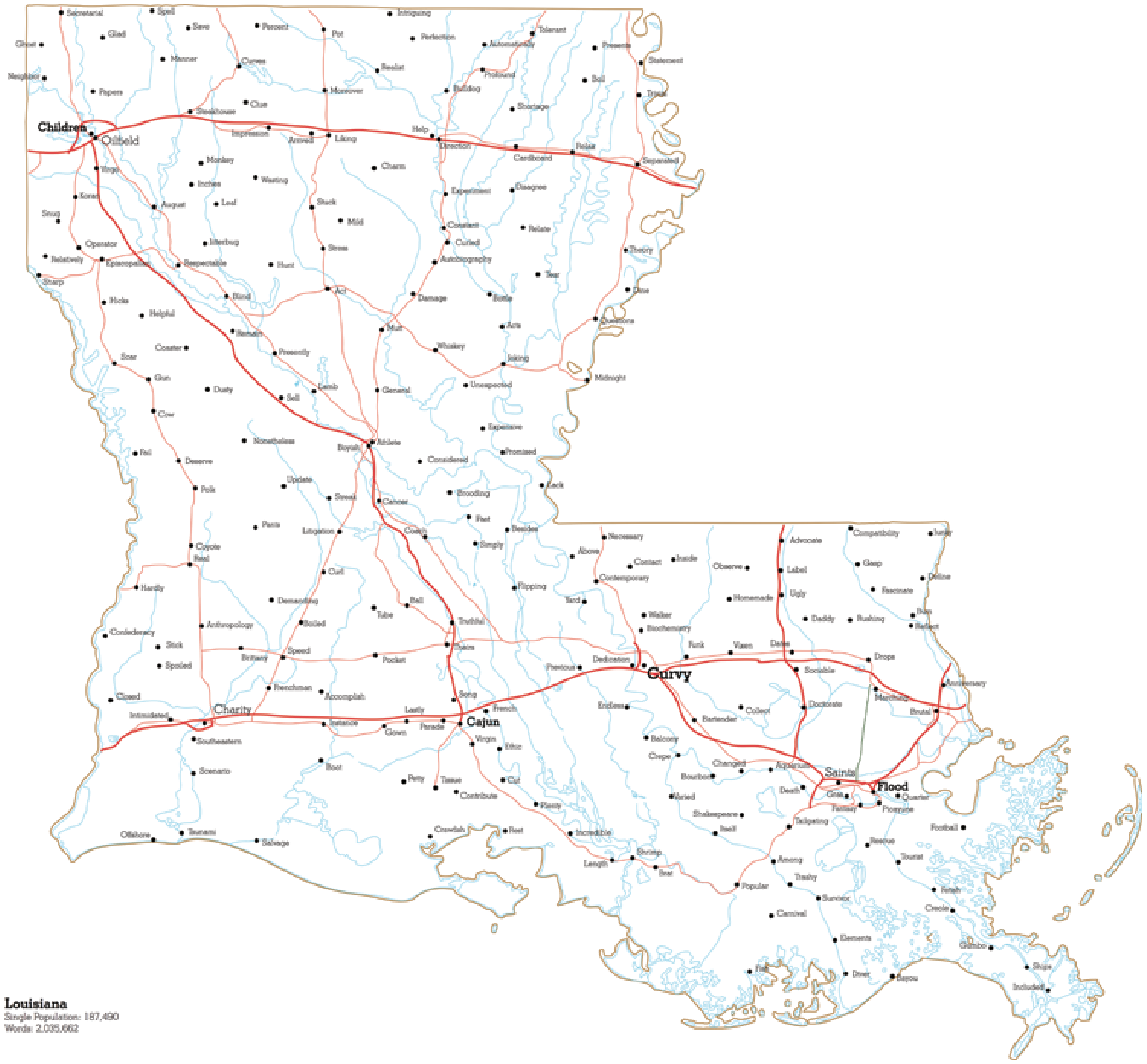


Figure 1-11: Washington, DC map from A More Perfect Union (2011)



In Louisiana, shown in Figure 1-12, *Cajun* and *curvy* pop out at you, as does *crawfish*, *bourbon*, and *gumbo*, but in New Orleans, the most unique word is *flood*, a reflection of the effects of Hurricane Katrina in 2005.

Figure 1-12: Louisiana map from A More Perfect Union (2011)



People are defined by common demographic data such as race, age, and gender, but they also identify themselves with what they like to do in their spare time, what has happened to them, and who they hang around with. The great thing about *A More Perfect Union* is that you can see that in the data on a countrywide scale.

The same sentiment—where data points are recollections and reports are portraits and diaries—is seen in Felton’s reports, Clark’s atlas, and Parecki’s GPS traces. Statisticians and developers call this analysis. Artists and designers call this storytelling. For extracting information from data, though—to understand what’s in the numbers—analysis and storytelling are one and the same.

Just like what it represents, data can be complex with variability and uncertainty, but consider it all in the right context, and it starts to make sense.

Variability

In a small town in Germany, amateur photographer and full-time physicist Kristian Cvecek heads out into the forest at night with his camera. Using long-exposure photography, Cvecek captures the movements of fireflies as they prance between the trees. The insect, as shown in Figure 1-13, is tiny and barely noticeable during the day, but in the dark, it’s hard to look elsewhere.

Figure 1-13: A firefly in the night by Kristian Cvecek, http://quit007.deviantart.com/

Although each moment in flight seems like a random point in space to an observer, a pattern emerges in Cvecek’s photos, as shown in Figure 1-14. It’s as if the fireflies move along the walking path and circle around the trees with a predetermined destination.