Motorcycle Crashes and Causes

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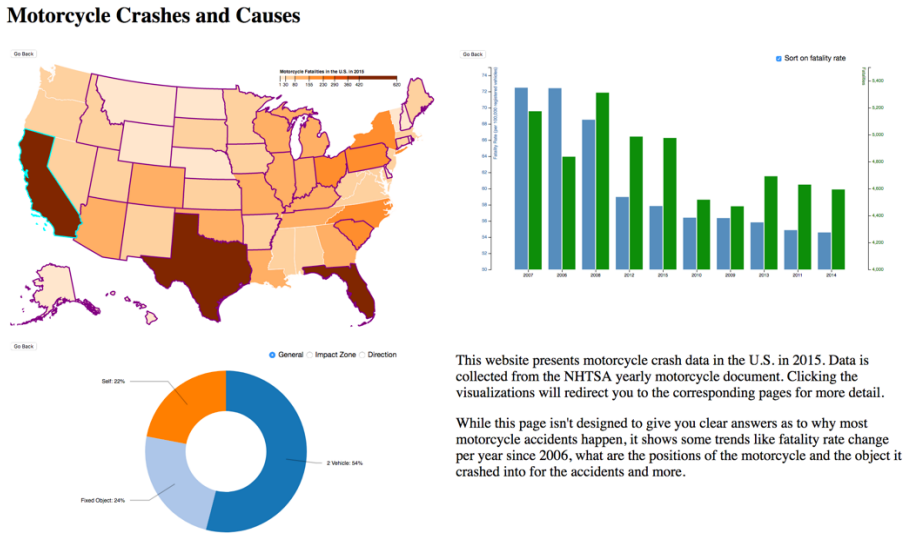

Fig1. These three visualizations show information about motorcycle fatalities in the United States. On the top left, the map shows fatalities per state using a choropleth map. On the top right, a bar chart shows the number of fatalities per year since 2006 and the fatality rate since 2006. Lastly, the donut chart shows more detail about how these crashes occurred.

Abstract—Can we look at motorcycle crash data using different visualization techniques to recognize trends or come up with ideas on how to be safer on the road? Traditionally, new riders are not provided enough information as to what to pay attention to to avoid getting in an accident. If we can figure out why and where most accidents occur, maybe we can reshape our new rider education system to look out for these hazards.

1 Introduction

Safety is a central concern when picking up motorcycling. There is more than one way to gain experience about riding safely. While seat time (time spent riding) is very important, new riders are encouraged to take the course offered by the Motorcycle Safety Foundation (also known as MSF). There, they have their first introduction to controlling the vehicle- but also, their first formal introduction to the risks involved in motorcycling.

New riders are taught that they are responsible for their own risk assessment when they hit the road on two wheels. They are then taught to control the motorcycle- and mitigate different types of road risks. In this paper, we will explore the causes of fatal accidents, as they may inform new riders as to what risks to look out for when they take to the streets.

By analyzing the causes of these motorcycle accidents, we may be able to figure out what to focus on riding to stay alive. The National Highway Traffic Safety Association (NHTSA) publishes a document every year that uses different visualizations and tables to show information about fatalities of the year and how the accidents occurred. Using the provided data to create my own visualizations, I was able to see some trends of the accidents and it helped me to watch out for certain things while on the road.

Within this paper, we will explore accidents in three major ways: first, by geographic location. The main variable that comes into play, which we account for via visualization, is local helmet laws. Second, we will look at data across years. Namely, fatality and fatality rate per 100,000 registered vehicles. This will show if motorcycling has become safer or more dangerous over the years. Third, we will look at how the crashes occurred, what was the position of the motorcyclist with respect to the object or vehicle they collided with.

The main questions we are hoping to answer with this paper are if helmet laws are an effective way to increase rider safety, if most accidents have a common attribute, and if lane splitting or filtering helps motorcyclists stay safe.

2 Related Work

Form of visualizations used in this project were largely influenced by Mike Bostock's D3 projects. Specifically, his U.S. county choropleth map, sortable bar chart, and pie chart are what helped complete this project in time [1].

Popular online motorcycle rider publication RideApart published an analysis of fatality rates and motorcycle safety in 2013 which was designed to illustrate how choices like alcohol and helmet use influenced the chance of fatal motorcycle crash [2]. The map-based visualizations in this work served as inspiration for my own geographic visualizations- for example I was immediately struck by the increase in fatality rate in the southern United States, colored in bright red. However, I saw room for improvement in the use of color scale to show more nuanced data and interactivity to boast data.

An additional related work worth noting in the Reddit "RideIt" survey, an annual survey of users of the /r/motorcycles subreddit [3].

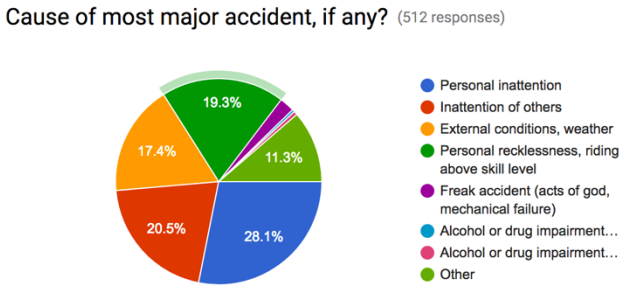

Fig2. Cause of most major accident pie chart from the RideIt Reddit survey of 2017

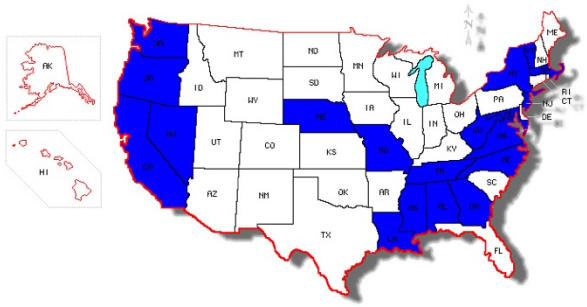

Fig3. Map showing states with mandatory helmet laws in the United States, featured in the RideApart motorcycle safety analysis

The results which were generated in pie charts were the most interesting to me- of nearly 1,000 riders, 50% reported having been in an accident of some type, with personal inattention as the leading reported cause of accident (28% of respondents). These charts sparked an interest in how motorcycle accidents were caused. While the breadth of data available through this survey was exciting to me, I was also aware of how great a role selection bias played in how the data could tell a story about crash risk. This is in part why I chose to focus on fatality in publicly available crash data, for which personal accounts provide little perspective.

3 Data

Almost all data used in this project is provided by the NHTSA. They have the most comprehensive crash statistics compared to other organizations. The data available in their "2015 Motorcycle Traffic Safety Fact Sheet" helped me decide what data I can and can't show [4].

Unfortunately, the data available through NHTSA isn't enough to answer some of my original questions. It also isn't detailed enough to show if lane splitting is safer since California has one of the highest number of fatalities in the country but it also has a very high population and year round nice weather which allows more people to ride more often. In order to show the population of each state, I used the United States Census Bureau's website, inside the "Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2016" file [5].

The helmet law information was brought from the Insurance Institute for Highway Safety website [6]. They have a map that shows which states have no laws, which states have partial laws, and which states have universal laws. It also explains the partial laws in details per state so I can see if it covers most riders or not. In most cases, it only covers a very small portion of riders.

4 Visualization

The most complex idiom in my project is the United States state map. It maps to the data provided by the NHTSA to accurately show the number of fatalities both using a tooltip and via color coding. The tooltip, which appears when user hovers over a state, shows the state name, number of fatalities for that state and the helmet law.

The second idiom is the sortable bar chart that shows data from 2006-2015. It shows both the number of motorcycle fatalities and the fatality rate which is number of motorcycle fatalities per 100,000 vehicles registered. It can be sorted on the fatality rate since the rate is a more accurate way to measure the improvements made to rider safety.

Third is the classic pie chart. It shows more detail about how the accidents occurred. The radio buttons on the top change the data shown to different perspectives. The default value shows who was involved in the accident while the impact zone tab shows where the motorcycle got hit. Last, tab shows which way the vehicles involved were going when they crashed.

5 Design Decisions

The main theme of my design decisions was to stick to more traditional idioms for ease of use and understanding. The main page which has all snapshots of the different idioms is a good way to tell the user to click on them since the snapshots are too small to actually inspect the data shown. User, from past experience with other websites, will know to click on the snapshots to view the visualization in detail. Main page also lets the user know of this capability in text on the lower right corner.

Deciding to use a map for state data was an easy choice since state data is best shown on a map. A choropleth map was required to better show the difference between the states. I used the color scale to visualize my main variable of interest, the fatality rate.

I also wanted to show the different laws in different states. To visualize the laws without drawing primary focus from geography and fatality rate, I chose to change the border color while thickening the borders of said states. The lane splitting law is unique to California which is why I chose a unique color for it. Other states which have colored borders are the states that don't have a universal helmet law.

I chose orange and purple as the color palate for this map. Orange is a cautionary member of the traffic safety color map, so I felt it was fitting that darker colors of orange represented higher fatality rates. I selected the purple border color as a low-contrast color to keep the visual focus on the fatality rates.

I also wanted to show laws about talking on the phone while driving to see if the states that allow talking on the phone while driving have a higher fatality count than the ones that don't, but including that as well would have made the map too crowded therefore I decided against it. There are a great many legal nuances that could influence motorcycle crash fatality statistics, so I chose to only select the most impactful ones.

After seeing that some states have a much higher fatality count than my initial projections, I decided to include state populations in the tooltip to let the user know that these states have a high count partly because there are a lot of people living in them. Further context may include the number of registered vehicles per state, but this data was not easily accessible.

I would have liked to show that some states have high fatality count because the riding season in these states is longer than the rest of the country thanks to their climate but again, I didn't want to make the map too crowded and lose the user's focus by trying to give too much information. Plus, it is common knowledge which states have nicer weather throughout the year so the user can probably come up

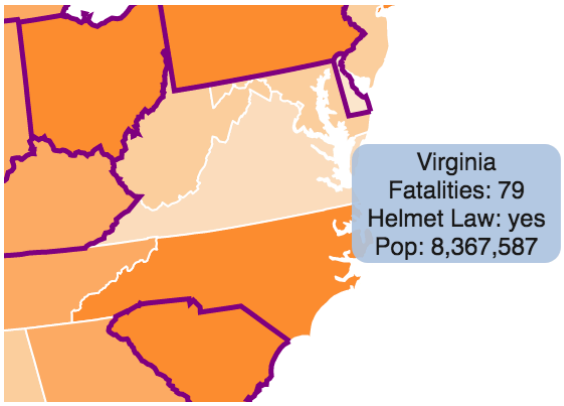

Fig4. Tooltip found on the choropleth map idiom that shows the number of fatalities, population and the helmet law in that state.

with that conclusion themselves. An additional advantage of geospatial display here is that it can be correlated with climate.

My initial thought was to create a connected scatterplot for fatality rate and count throughout the years. I got the connected scatterplot idea from the Info Vis paper "The Connected Scatterplot for Presenting Paired Time Series" [7]. Later, I decided that a sortable bar chart would be the best way to go about it. Availability of d3 resources was a major reason initially but as I worked on it, I realized that it is easier to read than a connected scatterplot since showing time is difficult on a connected scatterplot and I don't have enough data points to have create a connected scatterplot which will draw the user in. With the sortable bar chart, I can show 2 different things. First, the change in fatality rate and count throughout the years. Second, since it can sort, I can show the highest and lowest fatality rates. This view tells me that until 2015, the fatality rate was mostly getting lower but it increased again in 2015 even though it is never as bad as it was in 2006-2007.

The pie chart which is actually a donut chart, is a good way to show the direction data because there aren't many categories to crowd the pie (3 colors each). Radial understanding is weaker than spatial understanding, so I thought this small data could be more easily understood in a donut rather than pie shape. It's easy to read and understand. I can show 3 different datasets using the radio buttons which saves from space and avoids a crowded page, and the data shown is closely related so the pie charts actually complement each other without having to show the user these charts at the same time. Even though pie charts are not very liked in the information visualization community, I decided to take my chances with it because I think they are ideal for showing big percentages and they will show my data without any confusion.

6 Analysis

In this section I will analyze the 3 idioms used in this project and determine whether this project was able to answer any of my original questions.

6.1 Motorcycle Fatalities per State

This idiom shows the United States map divided into states, colored according to the number of fatalities occurred in that state in 2015. Some states have purple borders which means that that state does not have a helmet law.

While most traffic rules are the same for all the states in the United States, some laws change from state to state. The most important (and often controversial) law that protect motorcyclists is the helmet law. Even though there are age limits in most states, the

Idiom	Choropleth Map
What: Data	One nominal, one quantitative attribute, and two categorical attributes
How: Encode	States are colored based on the number of fatalities. State borders are colored based on state laws
Why: Tasks	Find trends, outliers, extremes, and compare values

Table1: What/why/how framework of the choropleth map

age limits are very low (generally 17-20). I chose to include states with age limit helmet laws only with the states that don't have any helmet law. Helmet law requires motorcycle operators to wear a Department of Transportation approved helmet on the road.

States that do not have a universal helmet law are shown with purple borders.

Only California allows motorcycles to share a lane with another vehicle which is called lane splitting or lane filtering, and therefore California has cyan borders. This unique policy is massively controversial among motorcyclists- while anti-filtering groups claim that lane splitting increases risk for all vehicles on the road, their opponents argue that filtering is potentially safer and reduces traffic. California is therefore lauded as a very unusual state in the United States and deserved its own color. It also has universal helmet law and therefore doesn't conflict with the purple bordered scheme.

Analyzing this map shows that higher number of fatalities happened in big southern states. The reason for this is that the map doesn't look at a fatality rate but actual numbers, and the bigger a state is, the larger number of riders it will have. Also, southern states have a higher average temperature which means people who only ride in fair weather can ride more frequently. Last but not least, even though motorcycle apparel companies have been doing a great job coming up with clothes that are safe but still let a lot of air in, it is never as comfortable as riding without any safety gear on. As a result, people in warmer climates are more likely to ride without any gear on, while riders in cold climates prefer and benefit from protective armor. While the warmer states will have more people riding for more days a year, it will also have more people riding without any gear because they need to decide between their personal comfort and safety.

It is very interesting to me that Florida, which has 7 million less people in it than Texas, has a much higher fatality count than Texas. This may have to do with lack of driver's education in Florida, or because it is frequented by older people who have retired. Since they have slower reflexes, they might be causing these accidents either on their bikes or in their cars. Florida's status as a vacation destination may also factor into the fatality rate.

6.2 Fatality Rate Throughout the Years

Motorcycling has advanced so much in the past 10 years. Motorcycles are safer now thanks to technological innovations like traction control, antilock braking, and wheelie control. In addition, most cars these days have better accident avoidance systems like blind spot sensors and backup cameras. All of these new automotive technologies reduce the chances of a motorcyclist getting in an accident by increasing rider visibility to vehicles and increasing the rider's ability to control the motorcycle in various road conditions.

Not only motorcycles but also motorcycle apparel has advanced in recent years. Helmets have to pass more difficult tests now to obtain Department of Transit certification, and external validating agencies like Snell and ECE continue to raise the bar on helmet's ability to protect upon impact. A lot of R&D goes into building durable motorcycle jackets, pants and shoes that have adequate armor as well

Idiom	Ordered Bar Chart
What: Data	two quantitative attribute, one categorical key attribute
How: Encode	The two bars per one categorical attribute(year) show the fatality rate and fatality count. They can be sorted based on fatality rate via the checkbox
Why: Tasks	Lookup and compare values

Table2: What/why/how framework of the ordered bar chart

as good abrasion resistance for high speed slides. Kevlar motorcycle jeans are very popular but generally disliked because of their poor air flow.

Textile pants and jackets are ideal since they come in layers for any weather and provide good overall protection but may not be as protective at high speeds since they are designed for more touring and commuting purposes. Motorcycle apparel has become not only safer, but more popular as manufacturers pour resources into styling.

People install aftermarket exhaust systems for their loud sounds, and while some may think that they sound worse or better, the main idea behind it is that more people will pay attention to the rider if they can hear him/her coming.

There are also courses for new riders, experienced riders and advanced riders. Some insurance companies even give discounts to those who have taken these courses. There are many people who make videos on video sharing websites which allows people to learn from others' mistakes. Rider's education has evolved. The most popular course by the Motorcycle Safety Foundation advocates ATGATT, which stands for All The Gear All The Time, and encourages new riders to choose to maximize safety through their choice of riding apparel.

While there are all these people working to make motorcycling safer, it is the responsibility of every motorcyclist to seek the better gear, and the safer bike. Nobody will put the helmet on a motorcyclist's head but themselves. That is where the helmet laws come into play but that is not the point here.

This idiom shows the fatality rate which is the number of fatalities per 100,000 vehicles registered and the actual fatality counts since 2006. Because it's a sortable bar chart, it allows us to see if any of these technologies and advancements mentioned previously has any effect on the fatality rate. It seems that fatality rate dropped significantly in 2009 and there were no significant changes in the following years. Looking at fatality rate rather than the fatality count is important since just because more people lost their lives doesn't necessarily mean that motorcycling has become less safe.

6.3 Causes of Fatal Accidents

There are three main ways a motorcyclist crashes. It either involves another vehicle, a motorcycle can crash into a fixed object, or a motorcyclist can fall off their bike for various reasons, like taking a corner too fast. This idiom dives into these causes and supports my theory that most accidents happen because a car doesn't see the motorcycle and drives in front of them.

The direction tab shows which way the vehicles were going at the time of the crash and it specifically shows that 41% of collisions that involve two vehicles happen when the other vehicle is turning left. This can either be when the vehicles were going in the same direction and the other vehicle did not see the motorcycle and changed lanes onto him/her or the car was coming from the opposite direction, did not see the motorcycle coming and made a left turn in front of him/her, causing the motorcycle to crash. It is easy while riding to not look ahead enough to recognize these hazards, that's

Idiom	Pie Chart
What: Data	Table: one quantitative attribute, one categorical attribute
How: Encode	Area marks with angle channel; radial layout
Why: Tasks	Part-whole relationship
Scale	One dozen categories

Table3: What/why/how framework of pie chart

why motorcycle courses always talk about the importance of scanning the road ahead constantly for potential dangers. This, combined with experience will force the motorcyclist to look for potential hazards and avoid them. The motorcyclist can additionally improve the visibility of both rider and motorcycle in order to increase the chances of being seen by left-turning motorists, particularly in being seen from the front. Headlight modulators and high-visibility gear are available for this purpose.

The impact zone tab shows where the motorcyclist was hit in collision. The greatest danger for motorcyclists seems to hit the front of the vehicle. Careful riders therefore should focus their scanning for hazards that could jump in front of their vehicle, and practice emergency braking and swerving to avoid collision in these cases. Even though it seems that motorcycles very rarely get hit in the rear, it is still a very real threat. Lane splitting also eliminates this threat since it allows motorcyclists to move forward when the traffic comes to a stop so they don't have to wait behind a car while another car may not be able to stop in time. In states that don't have this law, motorcyclists are encouraged to keep an eye on their mirrors and keep the motorcycle in gear at a stop to make sure that the person coming up behind them is not going an excessive speed.

7 Conclusion

Riding a motorcycle is dangerous, due both to the nature of staying grounded on two wheels and to the dangers of other vehicles on the roadway. Every motorcyclist accepts the risk of death or worse any time they get on their bikes. What I wanted to do was to analyze the causes for fatal accidents to see if I can learn something from other people's mistakes to help keep myself and others safe on the road.

One of my main objectives when starting this project was to see the impact of helmet laws on motorcycle safety. After creating the United States map, I was disappointed to find that the map isn't sufficient to show the effects. I could not visually discern whether helmet law had as large an effect as I initially thought. While my visualization technique may be at fault (I did not account for fatality rate), there are also many confounding elements. Reasons why a state may have a higher fatality count than another include climate and population, which I did not visualize. Removing the geospatial element from this visualization may have allowed a better analysis with respect to helmet law.

Another objective was to see if most motorcycle accidents are caused by drivers not seeing the motorcyclist, which will justify the decade long cry for safety of the motorcycle community. The pie chart shows detailed information on this topic and somewhat confirms my theory. Most crashes involving motorcycles were 2 vehicle crashes (54%) and among those, 41% was from drivers turning left and not seeing the motorcycle. This reminds me to be careful when there is a chance of oncoming traffic turning into my lane to make a left turn and to make sure a driver sees me before passing them.

Third objective was to see if motorcycling has become safer over the years. If I was to use only fatality counts per year, this would have led me to a wrong conclusion since fatality count is different from fatality rate which is a more accurate, yet not perfect, way of

measuring safety. The bar chart shows that it is safer now than it was 10 years ago.

8 Final Thoughts

This project was the most interesting project I had to make to date. Not only did it force me to learn d3 and practice javascript, it also taught me about the information visualization community which I didn't even know existed and how much thought and research goes into making sure information is conveyed clearly and fast when visualizations are used.

One of the major problems I faced was displaying the helmet law for each state. Choosing the right color is a difficult process since many states are affected so if it's too bright, the user won't want to look at it, but if it is too dark, user won't be able to understand the difference between a state with the law and a state without.

Last but not least, writing this paper was a very different experience for me since as a computer science student, I am not expected to write many papers but it is the only way to explain some of my findings and thoughts about my visualizations.

9 References

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