

Introduction

I examined a dataset about professional mixed martial artists, with an emphasis on those who have competed in the UFC (Ultimate Fighting Championship). The data consists of high level measures of fighter performance (e.g. number of wins and losses) as well as more granular measures (e.g. mean strikes landed per minute). It also contains various attributes such as height, weight class, country of origin, and the gym they train at. The majority of the data was collected from ufcstats.com and was merged with two related datasets from sherdog.com. The main benefits of the sherdog data were the inclusion of fighters' home countries, which were not present in the dataset I collected, and outcomes of specific fights as opposed to my aggregated data. Note that ufcstats.com is tied to the official promotion while sherdog is a third party website.

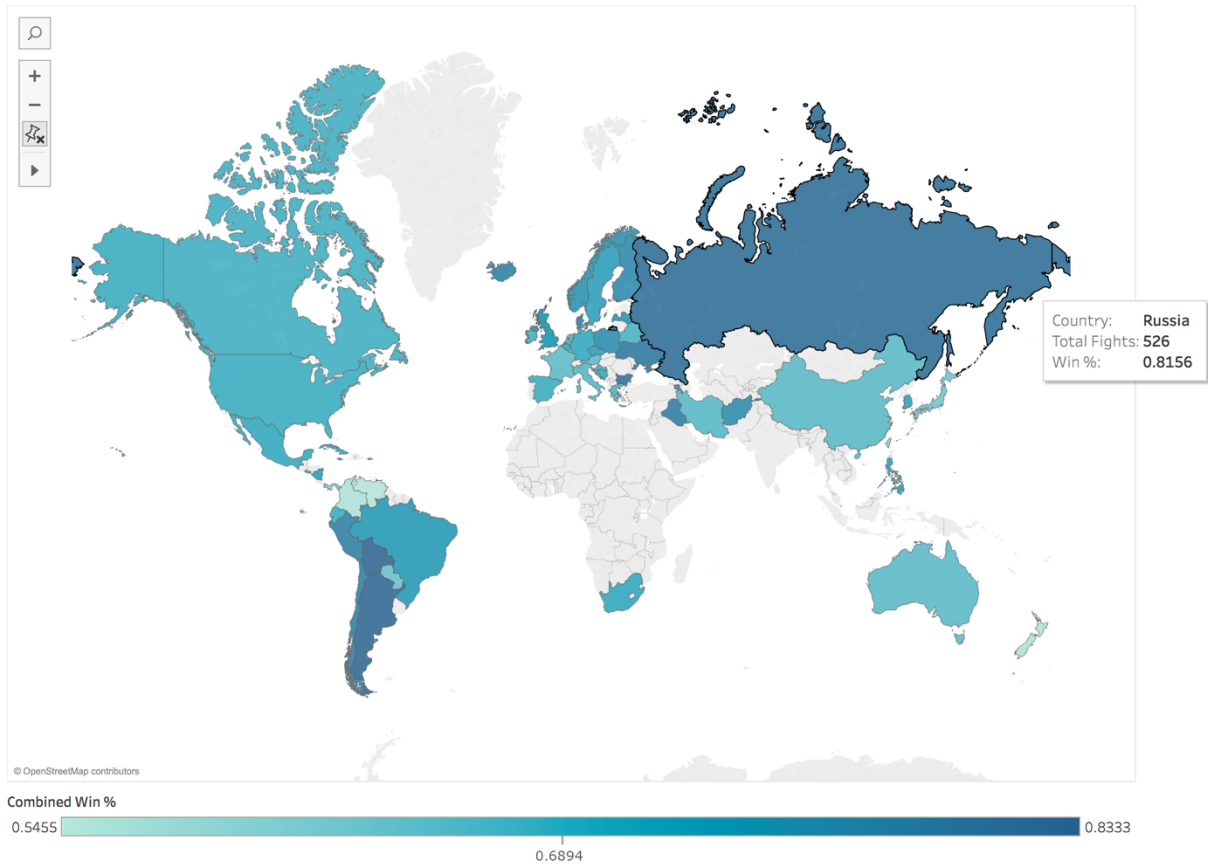
Martial arts have been popular for most of human history, with cave paintings from thousands of years ago depicting rudimentary fighting sports. *Mixed* martial arts can be traced back to the sport of pankration, appearing in the ancient Olympic games in 776 BC. However, the sport as we currently recognize it is rather new, and it wasn't until 1993 that the UFC was established. When we consider the long history of, for example, major league baseball, it is not surprising that statistical analysis in MMA remains somewhat underutilized. The *Moneyball* revolution that transformed MLB front offices and spawned the 2011 blockbuster movie occurred over a century after the league was founded. MMA does track stats, to be sure, but they tend to be quite simple and the general consensus is that they are not particularly informative. Data visualizations, too, are used sparsely and tend toward the generic. This, combined with my personal interest in the sport, convinced me that it was ripe for a "data science" approach.

Generalizations are common in fight analysis at a number of different levels, and this data gives us a chance to explore them. Conventional wisdom, for instance, says that Russian fighters are often particularly challenging opponents, largely due to their dominant grappling honed by the country's intense youth sambo programs. At a team level, Canada's Tri-Star Gym has gained a reputation for an effective but perhaps overly-conservative style characterized by low striking output and a lack of finishes (i.e. fights going to a judge's decision rather than ending in a submission or knockout). On the individual level, Justin Gaethje is thought of as the most exciting fighter in the sport, with his propensity for knockouts and generally chaotic fighting style garnering him the nickname "The Highlight". Hundreds of these beliefs exist, and they provide us with plenty of questions to investigate: how does fighting style vary by country, by gym, by weight class? These questions, and more, helped guide this investigation.

Visual Summary

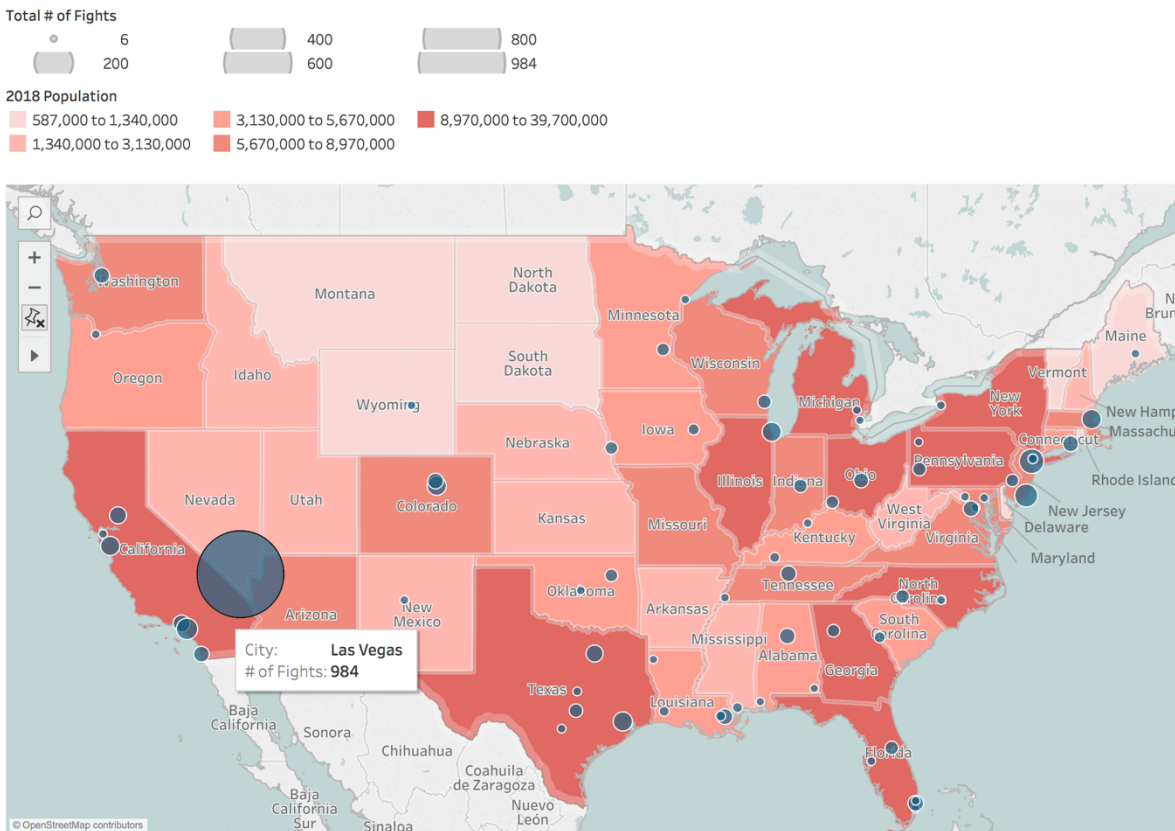
We start out with a simple visualization of win % by country. Not so surprisingly, Russia stands out as one of the most dominant forces. Interestingly, Argentina and Bolivia had slightly higher win percentages, but their sample sizes were less than 20% of Russia's.

Win % by Country

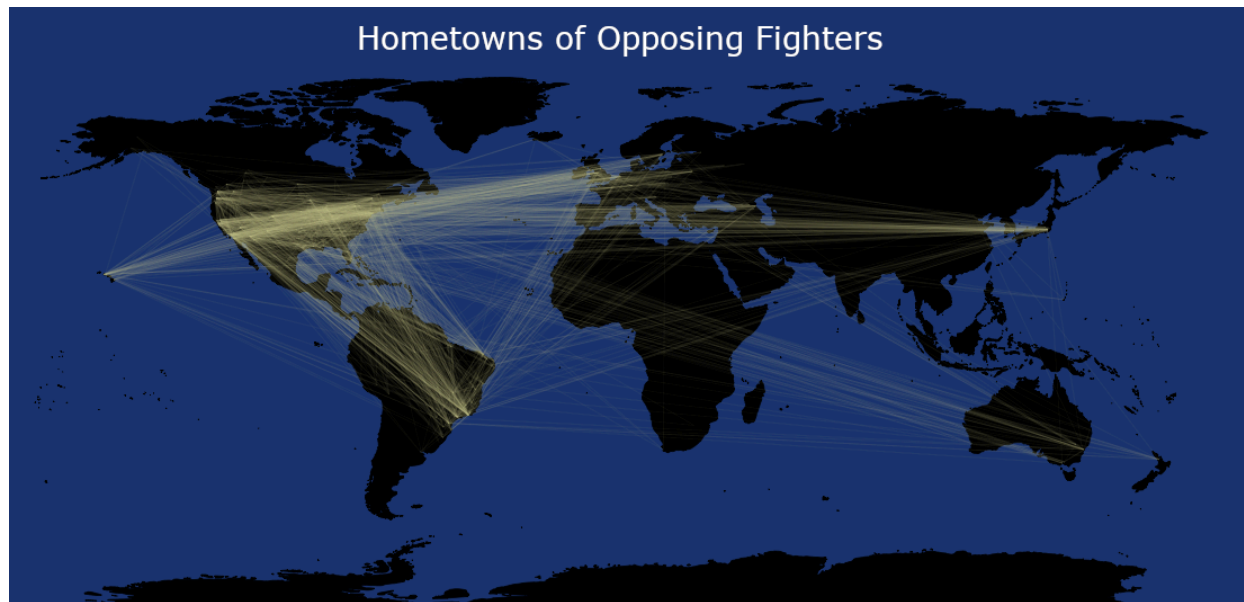


Next I visualized common fight locations in the US. Las Vegas dwarfs all other locations, playing host to nearly 1,000 UFC fights. Outside of Vegas, there are only a few locations in the western half of the country that get events. It also looks like the UFC visits states with higher populations more often, which makes sense.

Common UFC Fight Locations in the US



Here we see a connection map where the endpoints of each line represent the home cities of competing fighters (note that not all fighter hometowns are known in our dataset). We can see a few common matchups emerge: Brazil vs. USA, for instance.

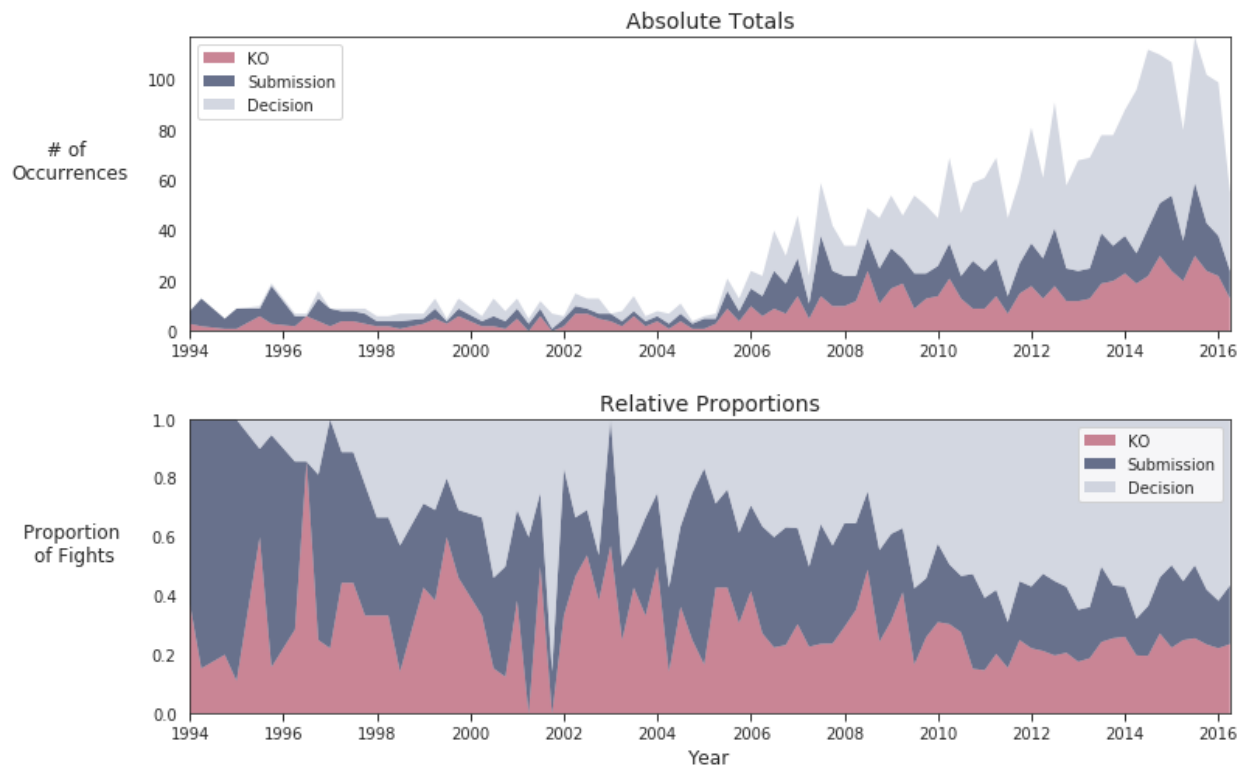


Most Common Win/Loss Records

Heatmap showing the distribution of win/loss records for fighters. The x-axis represents Wins (0 to 22) and the y-axis represents Losses (0 to 11). The color scale indicates the number of fighters (# of Fighters) corresponding to each record, ranging from 0 (light yellow) to 40 (dark blue). The highest frequency is observed for records with 7 wins and 3 losses, reaching approximately 40 fighters.

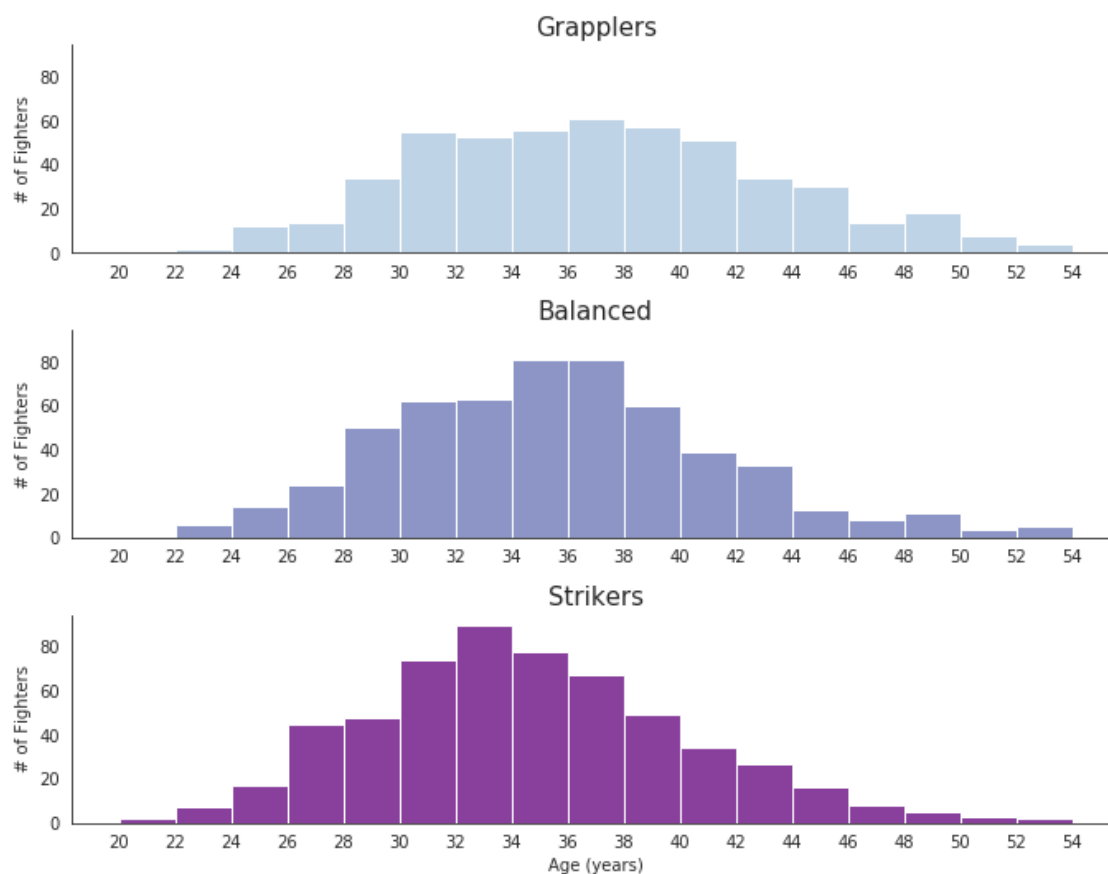
Next we look at fight outcomes in aggregate. These area plots show how fights have ended over the history of the UFC. Totals are computed quarterly since events were not always as frequent as they are now and some months would have zero fights. We can see that the total number of fights started to explode in mid 2005. This coincides with the first season of *The Ultimate Fighter*, a competition-based tv show with a UFC contract on the line that caused a surge in mainstream exposure and popularity. We can also see that submissions have become far less common over time, with judges' decisions becoming more common. The UFC was originally conceived as a showcase for Brazilian Jiu Jitsu (a submission grappling art), and it was incredibly effective initially. Over time, athletes adjusted and submissions became harder to find.

Quarterly Fight Outcomes

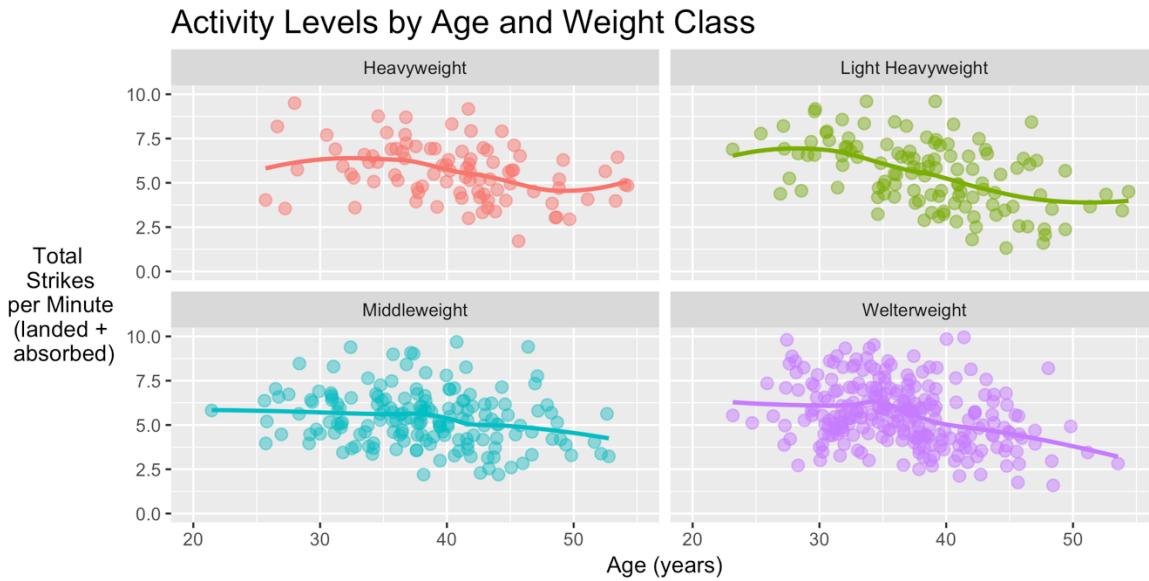


In a similar vein, I looked at average fighter age and fighting style (as assessed by the ratio of strikes landed per successful takedown – a large value indicates a striking-based style, while a low value indicates a grappling-based style). Striking-heavy fighters tended to be slightly younger than grapplers or fighters with more balanced styles. Note that the dataset considers all fighters who have appeared in the UFC, not just active fighters, so this gives us some further intuition for how the MMA meta-game has changed over time. This backs up what our area plot suggested, which is that we've seen a slow shift in emphasis away from grappling.

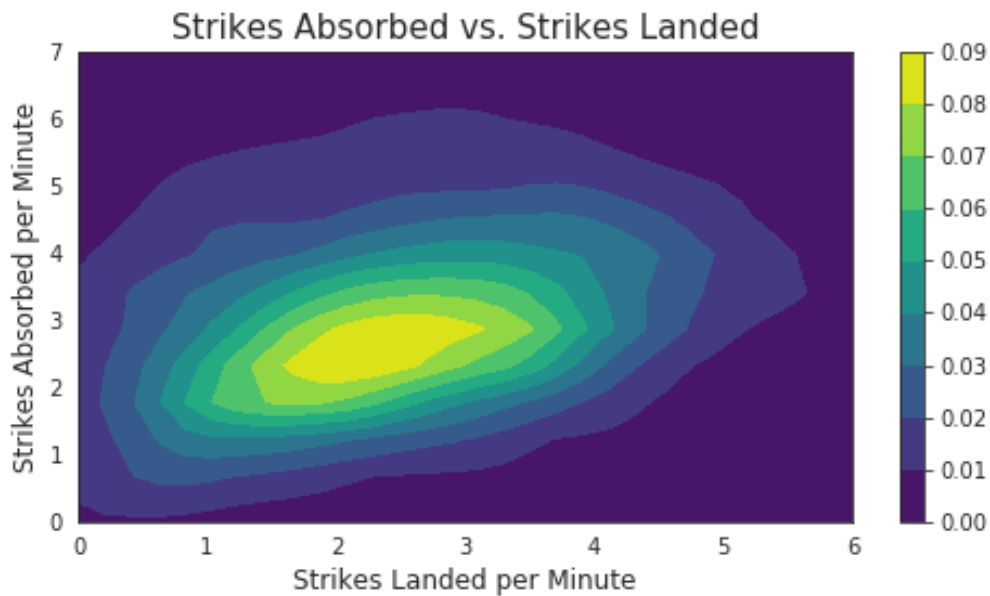
Age and Fighting Style



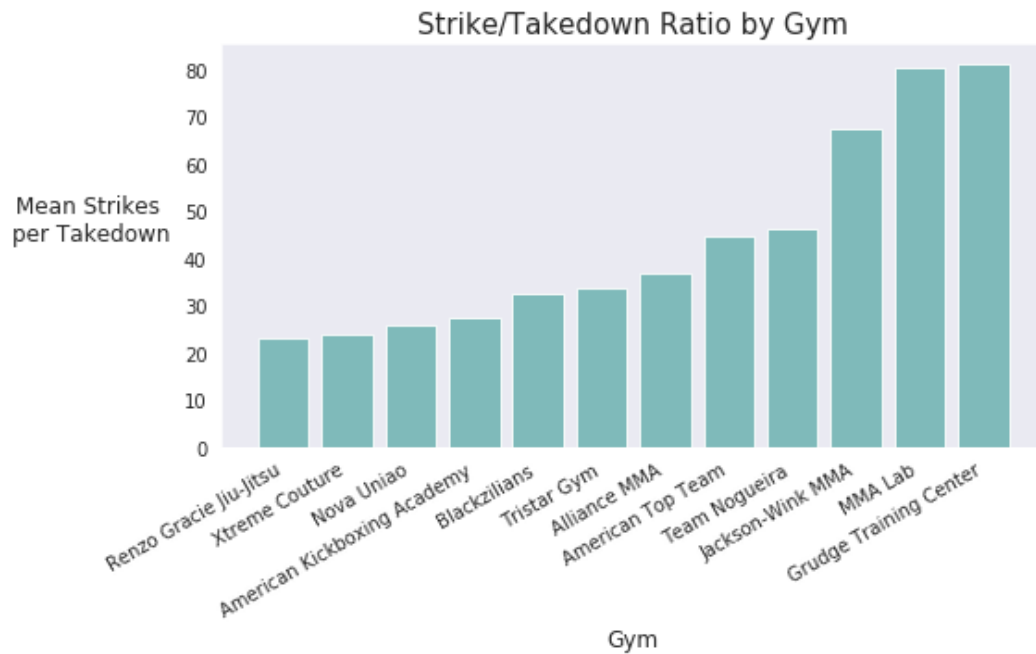
Continuing down a similar path of analysis, we can look at how striking activity varies by age. This is computed as the average number of strikes landed + absorbed per minute. Here I only examine the four heaviest weight classes as these have been around the longest. While the trend is not extreme, we can see that younger (i.e. modern era) fighters tend to be more active than their older peers and predecessors.



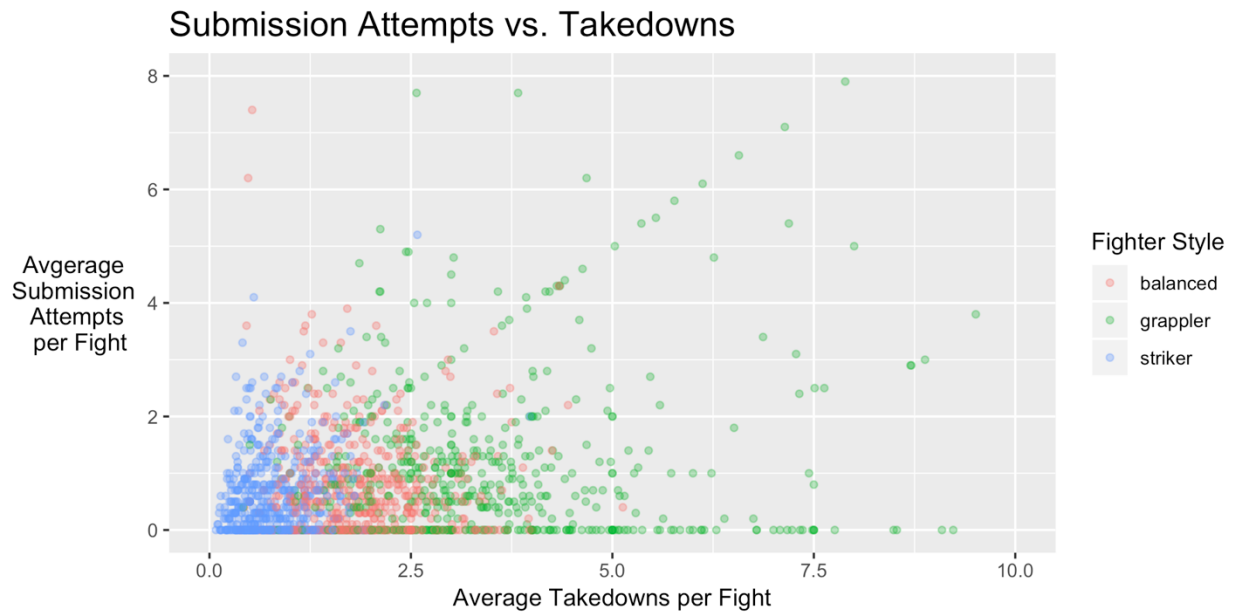
We can also consider how these two stats (average strikes landed/minute and average strikes absorbed/minute) covary. It's interesting to see a positive relationship between the two – one might speculate that more skilled fighters land many strikes (effective offense) and absorb few (effective defense). A likely explanation is that landing strikes requires one to be within “striking range” of the opponent, and that pushing a high offensive pace is inevitably accompanied by absorbing more damage. It also looks like there is slightly more variance in strike absorption rates for fighters with low rates of strikes landed. In other words, we see fighters with low landing rates and low absorption rates (indicating a conservative fighting style) as well as some with low landing rates and moderate to high absorption rates (indicating a less skilled fighter). But fighters with high landing rates are rarely have low absorption rates.



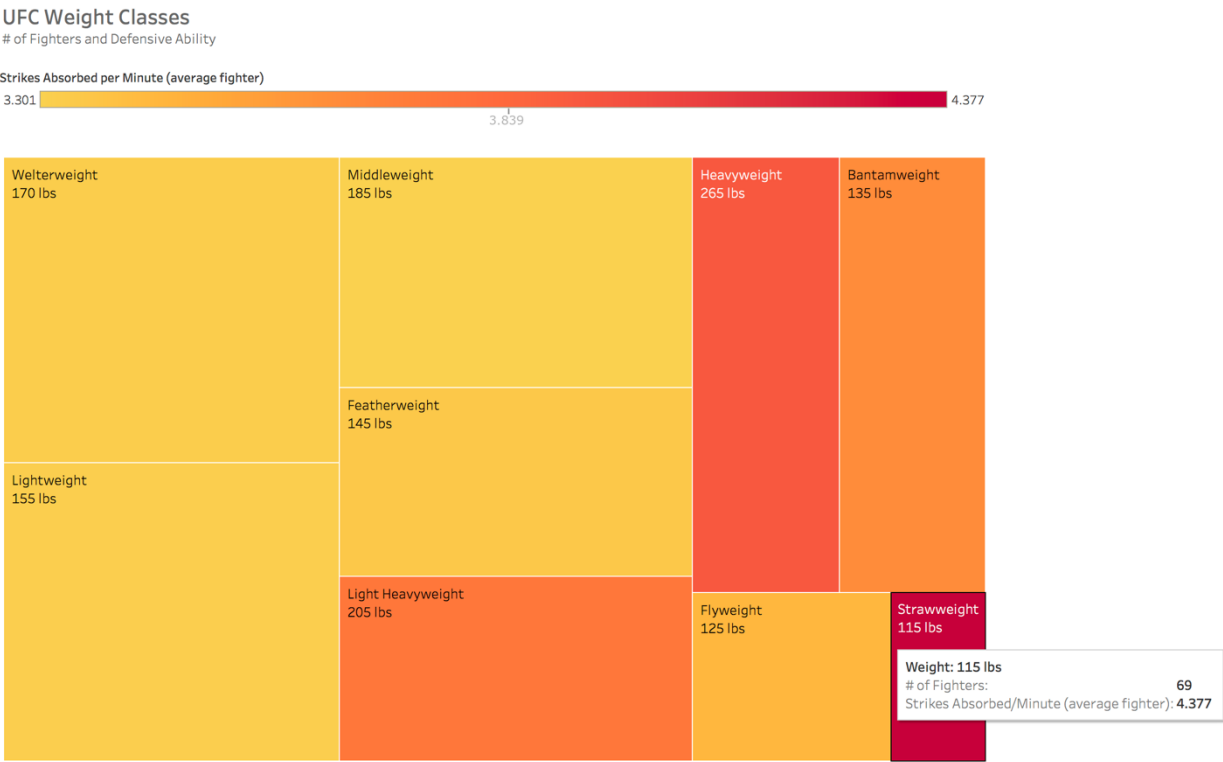
Here we look at the ratio of strikes landed to takedowns completed by gym. Renzo Gracie Jiu Jitsu is a BJJ gym (Brazilian Jiu Jitsu), while Xtreme Couture has a history as a wrestling-based gym, so their results seem fitting. More interesting is that American Kickboxing Academy is surprisingly grappling-focused. Tristar Gym lives up to its reputation for balance, appearing in the middle of the pack. Before this analysis, my impression of Grudge Training Center and MMA Lab was that they were both notably underrated gyms, but I didn't realize they had such a striking-heavy emphasis.



Here we look at the average number of submission attempts per 15 minute fight vs. the average number of successful takedowns per fight. This aims to generate a more nuanced view of fighter style. If we consider grappling-heavy fighters, there are those from a wrestling background who implement a control-based strategy mostly looking to neutralize their opponent (these are represented by the green points that lie on the right-hand portion of the x-axis, indicating they score many takedowns but rarely or never attempt a submission). Then there are a jiu jitsu-based fighters who are constantly looking to finish their opponent via submission, represented by green circles with large values on the y-axis. The almost perfectly linear line at $y=x$ is not an error; there are simply many fighters who attempt a single submission for every takedown they land.



Finally, we look at UFC weight classes by number of fighters and rate of strike absorption. The divisions with the most fighters are the ones that roughly match the medium-sized human (there are simply fewer people who are 265 pounds or 125 pounds in shape, and sports like basketball and football attract many of the larger athletes). These middle weight divisions also have the best defense, which is not surprising. Flyweight is something of an aberration, as a smaller division that also demonstrates a reasonable level of defensive skill.



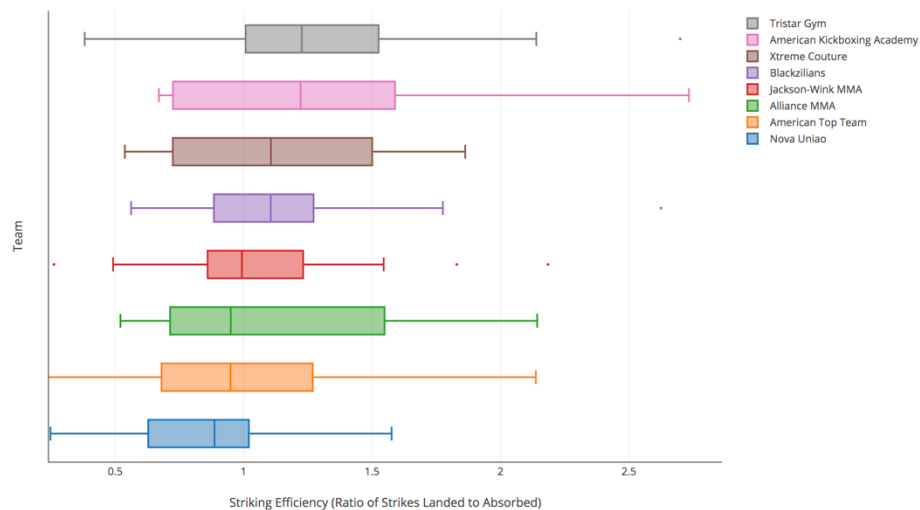
Storyline

One of my larger goals with this analysis was to develop a tool for comparison, something that would allow us to examine differences between teams, weight classes, or individuals. To do this, I built an interactive web app in Dash. It provides plenty of opportunities for the viewer to customize what comparisons to make (there are literally hundreds of billions of different plots that can be viewed on the app, mostly due to the fighter comparison polar plot), so I will pick a few to highlight here. First, here is what the overall app looks like (also available at <https://mma-math.herokuapp.com/>):

MMA Statistical Visualization Tool

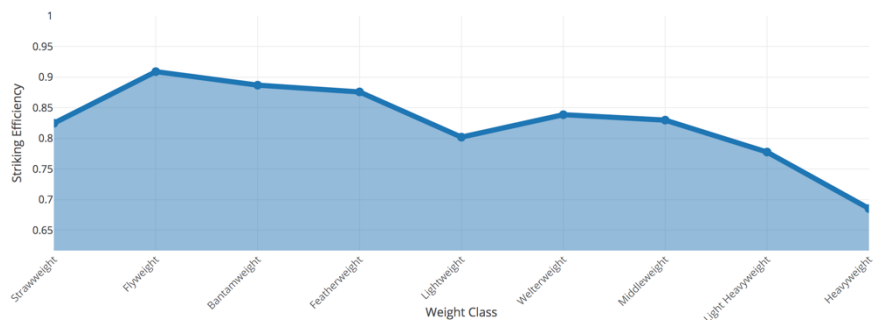


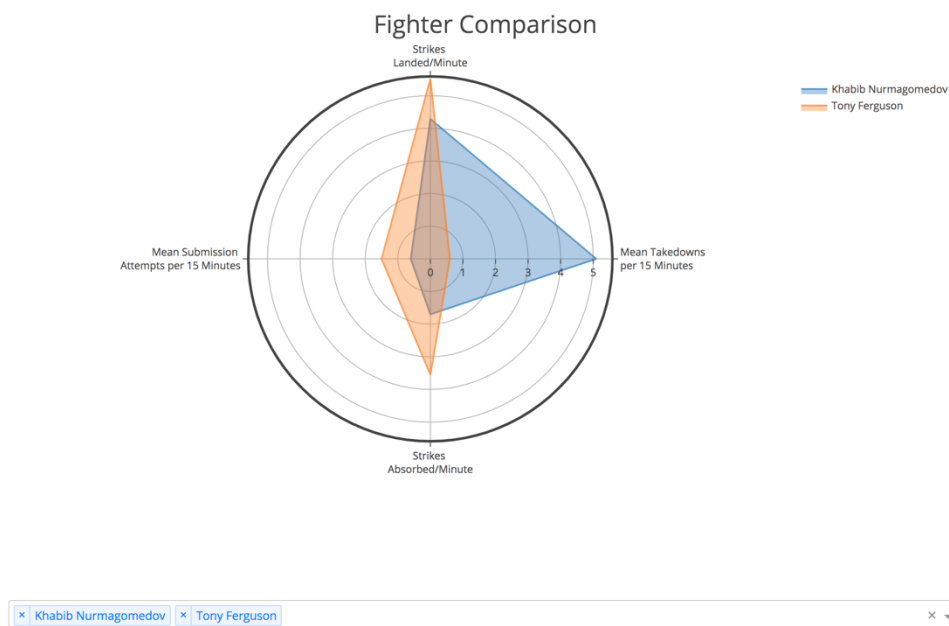
Comparison of Top Fight Teams - Striking Efficiency



Striking Efficiency (Ratio of Strikes Landed to Absorbed)

Weight Class Comparison - Striking Efficiency





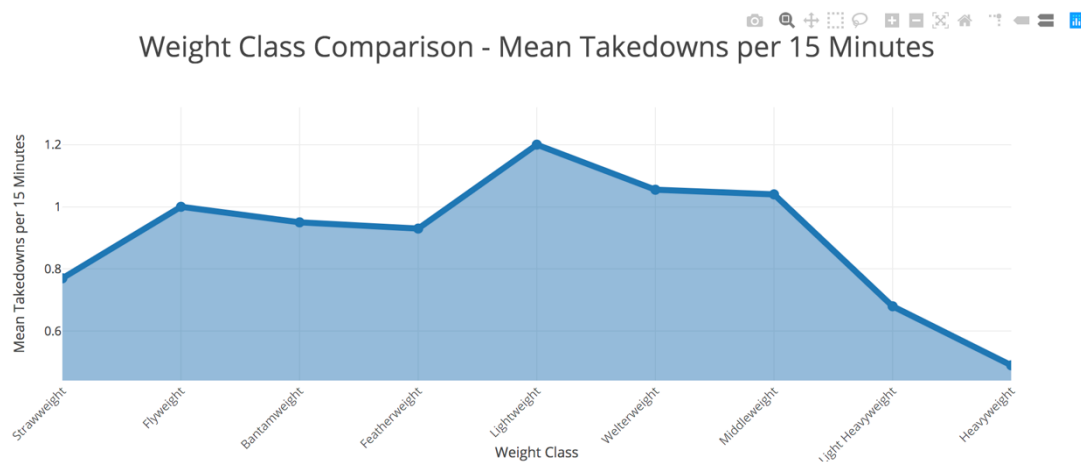
Reader Notes

- The "number of teams" slider will select the n teams with the largest number of fighters who have appeared in the UFC. So for example, selecting a value of 1 will only display data for American Top Team, which has had the most UFC fighters of any team.
- The weight class comparison plot uses the median value for each weight class.
- When viewing the team comparison plot and the weight class comparison plot, keep in mind that visual differences may seem magnified since the axes do not all start at zero. The goal here is to visualize small differences between teams, weight classes, and/or fighters, and I find the scale to be more informative when zooming in on the range of interest.
- Data was last updated April 13, 2019. I am still looking into ways to continuously update the stats without scraping the entire dataset over again.

The first chart is a box plot comparing the median fighter's striking efficiency between the eight fight teams with the most athletes who have appeared in the UFC (note that the user can select from 1 of 12 different statistics to visualize and limit the graph to between 1 and 12 teams). Striking efficiency (ratio of strikes landed to strikes absorbed) was one of the stats I was more interested in so I chose it as the default case when the page loads. As we saw with the bar chart in the previous section, Tristar lives up to its reputation as a skillful, strategic gym, maintaining the top efficiency of the major teams. Nova Uniao's poor performance here is perhaps a sign of the times – once considered one of the top gyms in the sport, they have struggled in recent years. Based on our earlier analysis, the decreased dominance of submission grappling and the rise of technical striking have been notable changes in the meta-game, and this environment makes it harder for a team with this striking style to succeed. (One interesting note from another box plot: Tristar has the lowest rate of striking activity (strikes landed+absorbed per minute) while Nova Uniao has the highest. This once again highlights the contrast between styles: brawling vs. controlled.) One final angle to consider here is the spread, as measured by the interquartile range, of each team. Some teams, like Jackson-Wink MMA, are more closely clumped, suggesting that they may tend to impart a consistent fighting style on all their athletes. American Top Team and Tristar are more spread out, showing a habit of working with fighters of all styles. Meanwhile, American Kickboxing Academy has one value that stands out in the form of Cain Velasquez (one of the few heavyweights to push a high offensive pace). He is often considered the prototypical AKA fighter so it's interesting how much his style diverges from the rest of them.

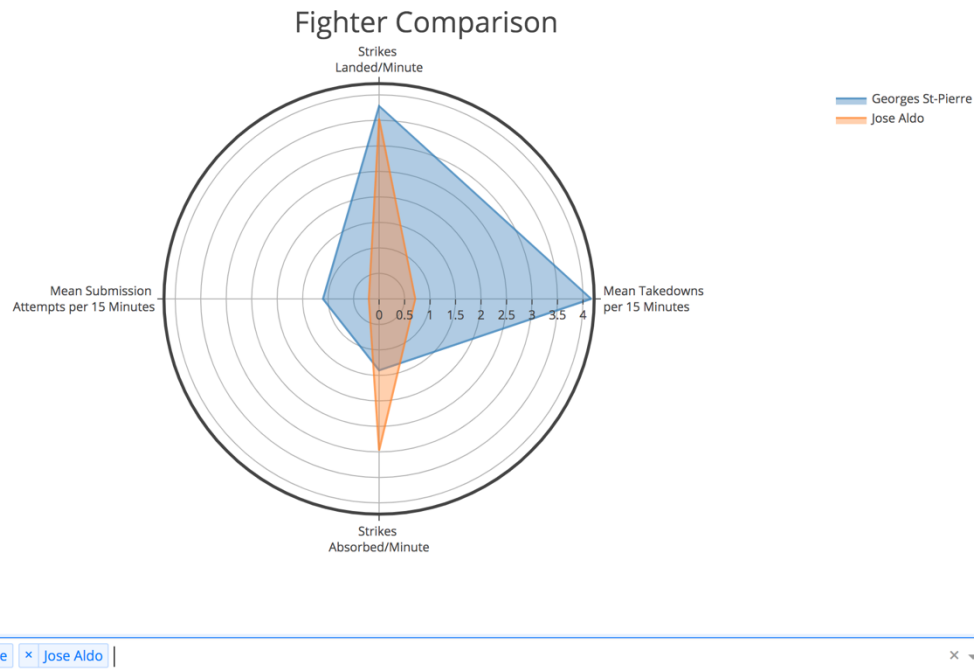
Since we have focused extensively on striking efficiency, I'll examine a different stat for the weight class comparison chart: average # of takedowns per 15 minutes, the length of 1 full fight. (Note: After careful consideration, I made the choice that the y-axis does not always need to start at zero for these box plots and area plots. The goal here is to examine small differences between teams, weight classes, and individuals, all of whom are competing in the same sport. If anything, we want to magnify the variance here, not hide it. I explicitly mention this in the Reader Notes section of the app so it should not be deceptive to readers. I know this is a controversial topic in the data visualization world but I believe this is a reasonable exception to the rule.)

Here we can see that takedowns are more prevalent in the middle weight classes and less common at the extremes, particularly on the heavier end. Lightweight in particular wrestling-heavy. My theory is that a wrestling-heavy game plan is less effective at the heavier weight classes due to the risk of a knockout. Wrestling is an effective way to score points, but when the fight can end with a single strike this isn't as useful. On the other hand, strawweight is the lightest weight class and also has a low rate of takedowns. Their speed and scrambling ability could make control-based game plans difficult to implement. In addition, strawweight only exists as a female division, and fewer women seem to come to MMA from high school/college wrestling backgrounds than men. The division hasn't been in the UFC for as many years, so many are relatively recent converts to the sport who started training kickboxing, jiu jitsu, or MMA as a hobby and ended up turning it into a career. It's extremely rare for adults to start training wrestling recreationally post-college – the wear and tear on the joints makes it more suited to the young.

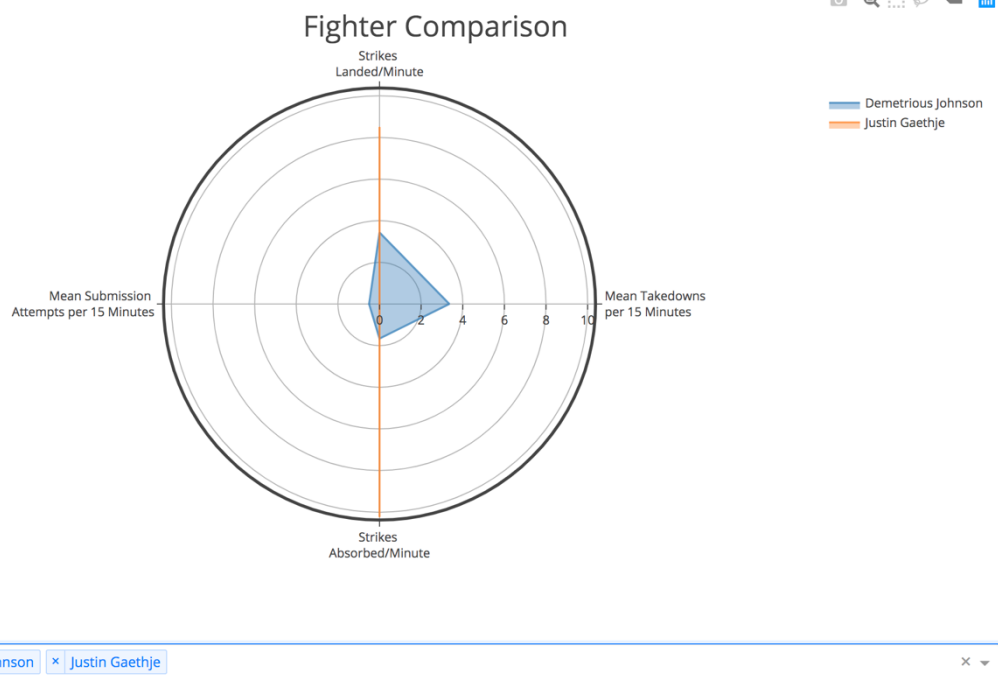


Finally, we examine what is probably my favorite part of the project: the fighter comparison tool. This polar chart allows users to overlay multiple athletes on one chart to get a direct comparison of their fighting styles. Below, I show the graph of what I consider the two greatest fighters in the admittedly short history of the sport: George St. Pierre and Jose Aldo. It's worth noting that GSP fought primarily out of Tristar, while Jose Aldo represented Nova Uniao (the two teams we focused on in the box plot discussion). St. Pierre was known as an exceedingly well-rounded fighter who blended the grappling and striking arts better than anyone, and this visualization largely supports that. Aldo is known for his ironclad takedown defense and technical striking. I was surprised that his rate of strike absorption is that much higher than GSP's, since his defense is generally considered to be excellent. The likely explanation is that GSP favors a wrestling-heavy game plan where he can control his opponent from top position, where he is at minimal risk of being struck. Aldo simply spends more of the fight on the feet engaging in striking exchanges. Regardless, I found it

interesting to visualize just how different their fighting styles are. Clearly there is no single style that allows for greatness. This also underscores just how dominant GSP was – Aldo’s resume dwarfs 99% of fighters’, but GSP’s stats here make him look ordinary.



As one final tidbit, I'll show the graph comparing Demetrious Johnson and Justin Gaethje. Johnson is known as one of the most well-rounded fighters in the sport, while Gaethje has one of the most distinctively wild styles.



In case it's not clear, Gaethje's shape is just a long orange line. Zero takedowns, zero submission attempts, and a huge rate of both strikes landed and strikes absorbed. Johnson is actually known for pushing a high pace but it's overshadowed here by Gaethje's relentless pressure.

For those unfamiliar with the sport, I realize many of these takeaways may not seem particularly interesting. However, this was a fascinating exercise for me and, hopefully, for other fans (who I plan to share this tool with).

Conclusion

Ultimately, much of the conventional wisdom in MMA is backed up by data. Russian fighters are, on average, unusually effective. Tristar Gym does have a balanced, efficient style. Justin Gaethje is an insane anomaly whose fighting style differs significantly from almost every other fighter. These beliefs I introduced at the outset were all essentially confirmed.

We did uncover some surprising or interesting findings. There has been a reduction in the dominance of submission grappling over the past few decades, accompanied by an increase in striking volume and wins by decision. Fighting style does differ noticeably by weight class and team, sometimes in surprising ways (see American **Kickboxing** Academy's affinity for takedowns). Somewhat counterintuitively, there are strong similarities between the lightest women's weight class and the heaviest men's weight class by measures of both grappling and striking. And high levels of offensive striking output are almost always accompanied by high rates of strike absorption – even skilled fighters cannot escape getting hit when pushing a high pace.

Most importantly, we have developed some new interactive tools for comparing fighters. When a new fight is announced, I can now visit my dashboard and see how the two athletes match up. I believe there are also opportunities to add increased functionality to the app, such as giving users more freedom in selecting which teams to compare or visualizing an individual fighter's style relative to the average person in their division. I computed far more stats in the process of working on this project than I was able to fully highlight in this report. One next step would be using these additional stats to create a “nearest neighbors” search tool and visualization (e.g. enter “Conor McGregor” into a search bar, then return a list of similar fighters, perhaps visualized with the help of T-SNE or PCA).

Code

All code is publicly available in the following repo:

http://github.com/hdmamin/mma_visualizations

Citations

<http://ufcstats.com/statistics/events/completed>

<https://docs.google.com/spreadsheets/d/1z3QX0uWXv-XHX2Nfuj6zZHrfEeXI3A9CKWkrGaBzB8s/edit#gid=0>

<https://docs.google.com/spreadsheets/d/1sQOtIwkEiT4kwwRHw5bwi72ZJHXlAVcCNMImr-Ml6U/edit#gid=0>