Analysis and Visualization of the FAA Wildlife Strike Database

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Abstract— The need to create interactive visual representation of data and information is becoming more prevalent as society's ability and reliance on information storage increases. Applying this technology to prevelant areas of our society is essential. Currently there are almost 130,000 records of incidents where an airplane or other vehicle had an encounter with a furry or feathered obstruction, which resulted in damage to aircrafts, people, and wildlife. A bird strike is defined as a collision between a bird and an aircraft which is in flight or on a take off or landing roll. Birds represent a serious, but often misunderstood, threat to aircraft. The bird and other wildlife strikes to aircraft result a great number of money in damage to U.S. civil and military aviation each year. The lives or the crew and passengers are also at risk. Since 1988, over 200 people have been killed worldwide as a result of encounters with birds and other wildlife. The reported amount of damage to aircrafts, vehicles, and persons in relation to the number of bird strikes in a particular area were examined and analyzed. Military entities had fewer reports of damages, and had no reports where one hundred or more birds were struck. In most incidents, only one bird was struck resulting in damage in all categories for military and non-military entities. Non-military reports appeared more wide spread and frequent which may be due to the higher frequency of air travel. Deductions from the study show extracting useful information from data can seem easy but care has to be taken to weed out outliers and match the results with actual data and external sources to see if there seems to be something wrong with what the data points to or what the external sources claim or if anything seems to be different than what common sense would suggest. There is a lot of data indicating wildlife strikes that happened from 1990 to 2010, and the visualization of the migratory patterns of the birds may enable the pilots to avoid high-risk paths. Details provide additional information that can also allow pilots to be more cautious during the stages of the flight with the highest risk of a bird strike.

Index Terms—Data and knowledge visualization, Graphs and networks, Information networks, Interactive data exploration and discovery

1 Introduction

1. Reported Bird Strikes and Aircraft Damage

With the advancements in aircrafts has led to jet travel replacing the noisier and slower piston-powered aircraft, which has resulted in an increased chance of these jets colliding with wildlife. As time passes, technology will only advance our aircrafts in a manner that makes them more stealth like, which will make aircrafts even more difficult to detect for birds. Along with the change in mode of travel there has been an increase in air traffic worldwide for both military and commercial purposes. This increase in the frequency of air travel coupled with aircrafts that are increasingly more difficult for birds to detect, may lead to an increase in bird strikes in the future. Due to noise considerations, many airports are situated near natural wildlife habitats that provide shelter, nesting area, and feeding areas for wildlife that is not usually present in a metropolitan area. This result in a majority of wildlife strikes occurring within the immediate airport environment. Preserving these areas and the wildlife inhabitants of it are a global concern. The need to examine the number of bird strikes in a specific region is important to analyze this issue, and formulate possible methods of prevention. Identifying areas that have a higher amount of bird strikes compared to others may help identify areas that have a higher probability of bird strikes. Exploring the reported amount of damage in relation to the number of bird strikes in a particular area may help draw significant conclusions as well. Exploring these variables may reveal correlations between the number of bird strikes reported and the amount of damage reported in specific areas. Examining these variables may lead to results that will help identify factors that will lead to preventative measures being developed to decrease the number of bird strikes, and finding reasons for the rate of reports on bird strikes and airplane damage in specific areas. This information could be added to the FAA's Research and Development sectors critical information, which includes specific information regarding land use, wildlife detection methods and wildlife management techniques that can be readily used by airport managers.

1.1 Creating the Visualization

The data being examined in this visualization are the number of bird strikes reported in relation to the amount of aircraft damage reported for specific regions. Tableau Desktop Professional Edition version 6.1 was used to produce the visualization in figure 1. Tableau is a technology that allows drag and drop functions to create sophisticated visualizations. Tableau accomplishes this task by a patented query language that translates user actions into a database query and then expresses the response graphically.

The FAA Wildlife Strike Microsoft Access database was first downloaded from the FAA Wildlife Strike website. A new project was then created in Tableau. Tableau provides the ability to directly connect to a data source or, copy and paste tables into its interface. For this project the Microsoft Access database was directly connected to in order to allow for all of the fields to be easily accessible to be used in future visualizations for further analysis. After the visualization was loaded into Tableau all string attributes of the Wildlife Strike Microsoft database were loaded into the Data Window of Tableau under dimensions, and all numeric data types were loaded under the measures section of the Data Window. Tableau provides shelf's that allow the user to drag an attribute into a particular area to be the columns or row for the visualization. The BIRDS_STRUCK attribute provides the number of birds and wildlife struck. This attribute was dragged into the rows shelf. The DAMAGE attribute provides the level of damage caused to an aircraft by a wildlife struck. This filed utilizes abbreviated values that represent the level of damage to an aircraft from a wildlife struck. Null fields indicate that the damage to an aircraft from a wildlife struck is unknown. A value of "N" indicates no damage resulted from the wildlife strike. Minor damages, represented by a value of 'M', indicate that the aircraft can be rendered airworthy by simple repairs or replacements and an extensive inspection is not necessary. Uncertain damage, represented by a value of 'M?' indicates the aircraft was damaged, but details as to the extent of the damage are lacking. Significant, represented by a value of 'S' indicates the aircraft incurs damage or structural failure which adversely affects the structure strength, performance or flight characteristics of the aircraft and which would normally require major repair or replacement of the affected component. Destroy, represented by a value of 'D' indicates the damage sustained makes it inadvisable to restore the aircraft to an airworthy condition. The military have their own distinct values, and the level of damage is accessed by monetary value. Class A or value of "A" indicates over $2,000,000 in damages to the aircraft resulted from the wildlife strike. Class B or value of "B" indicates $500,000 to $2,000,000 in damages to the aircraft resulted from the wildlife strike. Class C or value of "C" indicates $50,000 to less than $500,000 in damages to the aircraft resulted from the wildlife strike. Class "E" or "N"or a value of "E" or indicates no damage or damage less than $50,000 to the aircraft resulting from the wildlife strike. The DAMAGE attribute was also dragged to the row shelf. The STATE attribute provides the state or territory in which the wildlife struck occurs. Tableau detects the state and territory abbreviations as geographic locations and stores their values as longitude and latitude values to be used in a map visualization. This attribute was dragged to the column shelf. The Quick filter was then utilized to narrow the data set to avoid returning unneeded null values.

A map visualization was then generated from the parameters used. The Quick filter for the map was then adjusted to show state borders. Tableau determined the STATES attribute was going to be used a geographic locations, and generated maps, and placed DAMAGES in the column shelf.

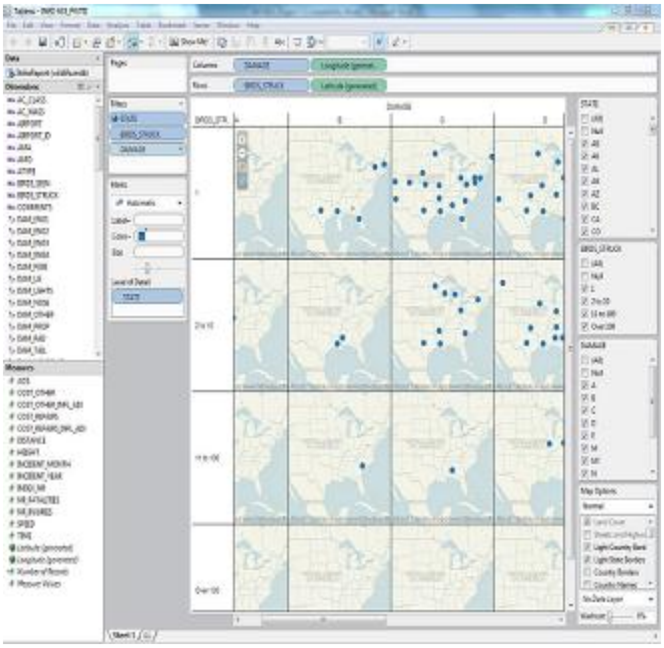

Figure 1: Visualization generated in Tableau after inputting parameters.

The resulting visualization consisted of a Row categorizing birds struck into the numbers reported, which were one, two to ten, eleven to one hundred, and over one hundred. Columns were categorized by the values that represent the reported damage to aircrafts from wildlife strikes. This presented four rows of maps each row listed the number of reported birds struck in relation to the level of damage reported for a particular region.

Figure 2: Completed visualization in Tableau

1.2 Data Visualization Analysis

Analysis of the number of reported birds struck versus the amount of damage sustained from wildlife strike to an aircraft was conducted from the generated visualization. Analysis of these variables was conducted to analyze any correlations between the number of bird strikes reported and the amount of damage reported in specific areas.

1.2.1 Military Damages

Class A (damages over $2,000,000) damages reports were the rarest of all damages reported between military and non-military entities. There were three Class A military reports from a wildlife strike. The states in which a military entity reported there were damages of this magnitude were Texas, Missouri, and Minnesota. In Texas, only one bird was reported being struck, which resulted in Class A damages. In the other two states, between two to ten birds strikes were registered. Class A damages made up the smallest amount of reported damages.

The span of Class B ($500,000 to $2,000,000 in damages) damages reported was slightly greater than Class A. Class B reports expanded to seven states. In the Southeast a range of one to one hundred birds were reported being struck. In the South West region of the U.S two to ten birds were reported being struck. For the two states in the New England region only one bird was reported being hit for both incidents. Class B damages made up the second smallest amount of reported damages.

The span of Class C ($50,000 to less than $500,000 in damages) damages reported was significantly greater than Class A or Class B reports, and expanded to all regions of the U.S except for the North West. The majority of reports consisted of incidents in which one bird was struck. The Class C damages resulting from one bird being struck spanned across all regions of the U.S. except for the North West. The reports of two to ten birds being struck increased significantly in the Class C damages than Class A or Class B. However, the reports of eleven to one hundred birds being struck was still a rare occurrence, as was the case with Class B damages.

1.2.2 Non-military Damages

Minor (M) damages being reported by Non-military entities were very common. M damages were reported in all regions of the U.S and almost all U.S states. Most M damages were incidents in which one bird was reported being struck, and the amount of reports consisting of two to ten birds being struck was comparable to the reports of one bird being struck. The amount of two to ten bird strikes reported for this category of damages spanned across the entire U.S. M damages consisted of the third largest amount of reports of 11 to one hundred birds being struck, which was seen in all regions of the U.S. except for the North West. The reports of over hundred birds or more being struck were seen across the East Coast, Texas, and Michigan.

Uncertain (M?) damages being reported by Non-military entities were common as well. M? damages were reported in all regions of the U.S and almost all U.S states as well. Most M? damages were incidents in which one bird was reported being struck, and the amount of reports consisting of two to ten birds being struck was comparable to the reports of one bird being struck for this category of damages also. The amount of two to ten bird strikes reported for this category of damages spanned across the entire U.S. also. The amount of eleven to one hundred birds being struck resulting in M? damages was not as wide spread as with M damages, showing no occurrences on the West Coast. The only report of one hundred or more birds being struck resulting in M? damages only occurred in the Delmarva (DE, MD, VA) region.

Significant (S) damages being reported by Non-military entities were common as well. S damages were reported in all regions of the U.S and almost all U.S states as well, which was seen in all Non-military damages reports. Most S damages were incidents in which one bird was reported being struck, and the amount of reports consisting of two to ten birds being struck was seen in the same regions as the reports of one bird being struck for this category of damages. The amount of two to ten bird strikes reported for this category of damages spanned across the entire U.S. also. The amount of eleven to one hundred birds being struck resulting in S damages was the second largest for all reports eleven to one hundred birds being struck and the only region reports did not occur in was the North West. S damages had the greatest number of damages resulting from over one hundred birds being struck.

Destroyed (D) damages were the least spread of all the reported Non-military damages. Reports of one bird being struck resulting in damages were seen in all regions of the U.S. except for the North West. The amount of two to ten bird strikes reported for this category of damages spanned across the entire except for the far South West, which was the least spread amongst all Non-military categories for damages resulting from two to ten bird strikes. For damages resulting from strikes of eleven to one hundred birds the only occurrences were in Ohio and Illinois. There were no reports of damages resulting from strikes of one hundred or more birds.

1.2.3 No Damages

The Non-military and military entities used the same value in the DAMGES field to represent no damages occurring. No damages resulting from a bird strike were the most wide spread reported for non-military and military entities and in all ranges from one to over one hundred birds struck. For strikes of birds of one to one hundred there were reports for all regions of the U.S. For strikes of over one hundred birds reports were seen throughout the East Coast and Midwest.

1.3 Inference from Reported Bird Strikes and Aircraft Damage Analysis

Overall, military entities had fewer reports of damages, and had no reports where one hundred or more birds were struck. This could be attributed to frequency of flight, flight rights, aircrafts used, or any other number of variables and further exploration with other variables will be needed. In most incidents only one bird was struck resulting in damage in all categories for military and non-military entities. In all cases where over one hundred birds were reported being struck the incidents took place on the east to south central coast. This may be occurring from migration patterns from the Atlantic and Gulf's, or any other number of variables and further exploration with other variables will be needed. Non-military reports appeared more wide spread and frequent which may be due to the higher frequency of air travel, but further analysis will be needed to determine.

2. Engine and Propeller Damage

Since it would be almost impossible to actually decrease the number of wildlife strikes to zero, it would be helpful to look at what engine makes and models are the most resilient to bird hit damage.

An analysis was performed by looking at data where the engines or the propellers at any location were hit in an airplane and the corresponding total resulting damage amount adjusted for inflation. The total damage per engine make and model was calculated and the amount was divided by the number of total such hits per make and model to get average damage per hit. The results can then be used for picking the best and the worst engines. To make sure the data was correct, additional information was researched for the best/worst contenders. A variety

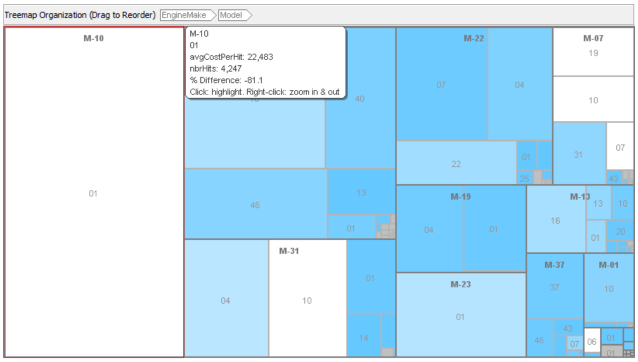

Figure 3: Tree Map organized by Engine Make, Model and sized by Avg Cost Per Hit

of visualizations were created with the ManyEyes tool and were used to arrive at meaningful conclusions since just one may have provided misleading information, for e.g, just finding out average cost might have been misleading due to outliers where only 1 engine of that particular make was damaged but with an extremely high repair cost. A treemap shown in figure 3 was used to group makes/models with the most number of bird hits while the bar chart in figure 4 was used to determine the makes with high and low average damage cost per Manufacturer.

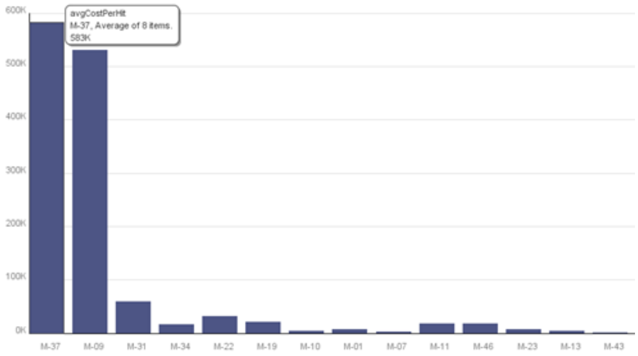

Figure 4: Average damage per hit vs Engine Make

2.2 Analysis of Damages

The two makes with the highest average repair cost per hit were Rolls Royce and BMW, which doesn't seem surprising at first considering that these are premium engine manufacturers but due to the same reasoning, their engines should technically be more tolerant to damage. Using figure 3 to dig deeper into individual models, it became apparent that the strange results were due to one model in each of the two manufacturer models that had so such damage cost, that they overshadowed the entire model lineup cost. Displaying the bar graph by models rather than make also reflected this as shown in figure 5.

Looking up additional details from the data, the outlier for Rolls Royce engine model number 31 (Olympus) seems to be because it was installed in a Concorde and

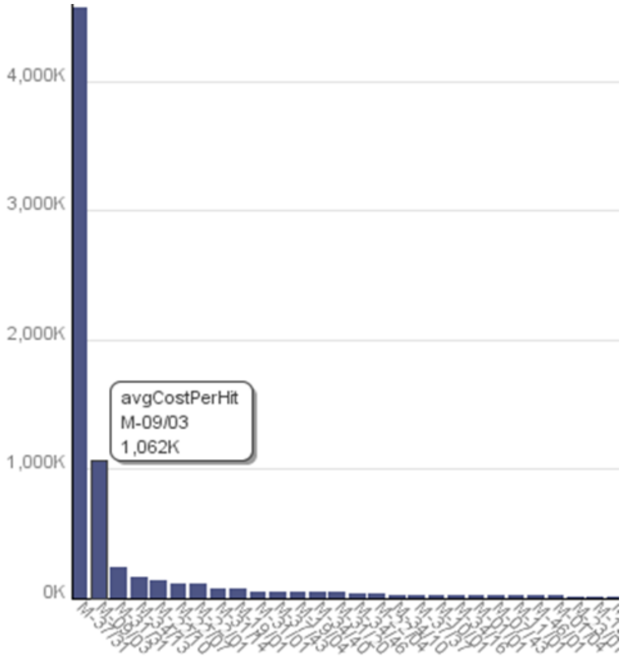

Figure 5: Average damage per hit vs Engine Model

was hit by Canada Geese and the damage was about 6 million in 1995 currency standards (9 million adjusted for inflation). Removing that one outlier, the BMW 710 series was hit 7 times and out of 4 times, the damages were substantial, making the average damage per hit to be $ 1.06 Million, making it the most vulnerable engine to bird hits. Other engines from BMW and Rolls Royce (RR) faired extremely well with one RR model hit 268 times with avg damage $25 K and other RR model being hit 18 times with avg damage only $ 484 while a BMW model was hit 30 times with an avg damage cost of only $38.

To find durable engines that could withstand a large number of bird hits with less damage, the data was filtered to show only the makes and models with average repair cost less than $10 K paying more attention to results with number of hits greater than 50. The PW100 family of engines by Pratt&Whitney had a total of 660 hits with an average damage cost of only $2585 and Avco Lycoming' 320 family had 267 hits with an avg damage of $ 1618. The winner seemed to be the LF 507 engine made by Honeywell in combination with Avco Lycoming which took 21 hits with zero damage costs.

The precaution to take while using the results in any matter would be to understand that the data is all self-reported with no checks for accuracy or authenticity. Anyone can access the records and modify them, much like Wikipedia articles.

2.3 Inference from Engine and Propeller Damage Analysis

What we found during the exercise was that extracting useful information from data can seem easy but care has to be taken to weed out outliers and match the results with actual data and external sources to see if there seems to be something wrong with what the data points to or what the external sources claim or if anything seems to be different than what common sense would suggest.

3. Affects on Wildlife and Geographical Regions

Bird strike is defined as a collision between a bird and an aircraft which is in flight or on a take off or landing roll. It expanded with other wildlife strikes such as bats or ground animals. Wildlife strikes can damage vehicle components, or injure passengers. Flocks of birds are especially dangerous, and can lead to multiple strikes, and damage. Depending on the damage, aircraft at low altitudes or during takeoff and landing often cannot recover in time, and thus crash.

Birds represent a serious, but often misunderstood, threat to aircraft. Most bird strikes do not result in any aircraft damage, but some bird strikes have led to serious accidents involving aircraft of every size. The bird and other wildlife strikes to aircraft result a great number of money in damage to U.S. civil and military aviation each year. The lives or the crew and passengers are also at risk. Since 1988, over 200 people have been killed worldwide as a result of encounters with birds and other wildlife.

3. Affects on Wildlife and Geographical Regions

Figure 6: Wildlife strikes in geographical regions by year, season

From Figure 6, we can see the largest number of strikes happens during the spring and fall migrations through 1990 to 2010. And some research shows that the bird strikes above 500 feet (150 m) altitude are about 7 times more common at night than during the day the bird migration season (Dolbeer). In addition, birds strike and terrestrial mammals' strikes were the majority type and occurred all over the US, especially on the east coast since it is the area with the most air traffic in the US. Bats and Reptiles strikes have occured less than birds and terrestrial mammals, and most of them were happened on the east coast as well. This would make sense as reptiles are not ususlly found at 500 feet and bats would usually detect airplane and avoid them easily.

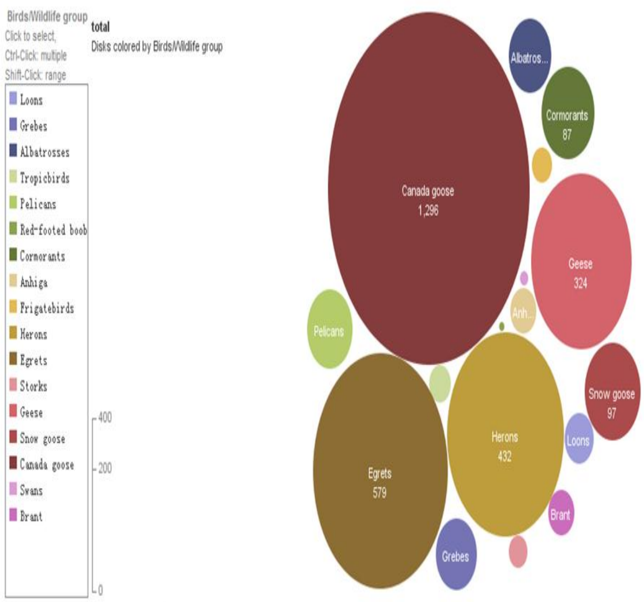

Figure 7: Migration patterns occur in 1990-2010

3.1 Analysis of Affects on Wildlife and Geographical Regions

Figure 7 indicates that animals most frequently involved in bird strikes are large birds with big populations, particularly gee and gulls in the United States. In parts of the US, Canada geese, Egrets, Herons, Geese and Snow goose are the large populations of wildlife strikes. In addition, the populations of Canada geese and military Snow goose have risen significantly while feral Canada geese and Greylag Geese have increased in parts of Europe increasing the risk of these large birds to aircraft (Allan, 1999).

3.2 Inference from Analysis of Affects on Wildlife and Geographical Regions

While the tools for creating charts and basic visualizations from data are available to everyone, there is still a lack of knowledge on how to properly use them. Most people have created a basic bar or pie chart before, but few realize how much you can do with even the few simple tools in Excel. Also, visualization websites can have an enormous impact on the world, by giving many people access to a lot of data that would otherwise be hard or impossible to obtain. There are lot of sets of data detailing the wildlife strikes occurring from 1990 to 2010. Although we can analyze the data by drawing charts in Excel sheet, it wopuld be better and useful to analyze it with some visual platforms critically and intuitively. ManyEyes is one such platform that allows a variety of visualizations suitable for a large variety of datatypes. The tool is developed and managed by IBM's new Visual Communication Lab. It allows users to upload data and automatically determines the datatypes. It offers interesting approaches to making data analysis more social and allows users not only to upload/visualize data, but also to download the data that exists on the sites. This is very useful, as it provides a much needed access to a huge variety of data and tools.

4. Bird Strikes by Season

The majority of bird strikes occur during the two primary migration periods a) the fall migration - September and October, when birds fly north to south, and b) the spring migration when migrating birds return north during the months of April and May. The least number of bird strikes occur during the winter months of December, January and February when the bird migration is minimal. This pattern is repeated every year. It is also known that different kinds of birds fly at different altitudes during the migration periods. The migration routes are particularly important to know because the majority of migratory birds are the large bird species and if they hit the aircraft can cause significant damage. Plus, knowing the migratory routes allows intelligent prediction as to which areas should be on high alert for bird activity. These large birds include geese, ducks and storks. The migration routes followed by birds are numerous and while some of them are simple and easily traced others are extremely complicated. "Differences in distance traveled, in time of starting, in speed of flight, in geographical position, in the latitude of the breeding and wintering grounds and in other factors all contribute to great diversity” [1]. No two species of birds follow exactly the same path from beginning to end.

It is important to have a large database of the bird paths with seasons which includes details on the type of bird and their path of flight. Knowing the migration seasons and tracking the migration routes can allow the pilots to plan flight routes around the known migratory patterns and reduce their risk of bird strikes. It is helpful to have a visualization of the migration path of the birds with different seasons and have the ability to zoom into the details about the kind of birds for such planning purposes.

4.1 Visualization using Tableau

Tableau allows data analysis through a wide range of visualization techniques including bar graphs, line charts, pie charts, geographic charts with longitudes and latitudes. Tableau Software provides many options, allowing users to match visualization displays with their data type. Tableau supports Ben Shneiderman’s “Information Visualization Seeking Mantra”, which states that users should be able to overview the data, zoom in on particular data sets, choose which data to visualize, and filter out unwarranted information. Using this Mantra as a guide, Tableau allows users to seek relationships between datasets and allows multiple options for extraction.
Tableau is used to capture the number of bird strikes during a particular month. Figure 8 shows number of bird strikes by month. The top months for bird strikes are September and October. In most cases the plane hit one bird. There are a few instances when the planes hit a significant number of birds

Sheet 1

	BIRDS_STRUCK			
Month of IN..	1	2 to 10	11 to 100	Over 100
January	3,827	943	45	1
February	3,297	670	47	3
March	5,532	849	37	3
April	7,832	1,020	53	
May	10,594	1,099	26	
June	8,633	1,065	43	1
July	12,788	2,108	113	5
August	14,191	2,671	158	7
September	14,133	2,319	134	9
October	13,505	2,081	108	2
November	7,356	1,654	120	5
December	4,260	1,067	85	4

BIRDS_STRUCK
- 1
- 2 to 10
- 11 to 100
- Over 100

Count of INCIDENT_MONTH broken down by BIRDS_STRUCK vs. INCIDENT_DATE Month. Color shows details about BIRDS_STRUCK. The view is filtered on BIRDS_STRUCK and INCIDENT_DATE Month. The BIRDS_STRUCK filter keeps 1, 11 to 100, 2 to 10 and Over 100. The INCIDENT_DATE Month filter keeps 12 of 12 members.

Figure 8: Bird Strikes at San Francisco during different months of the year

The visualization shows different kinds of birds that strike at the San Francisco airport in a year. It is clear that Gulls strike more than any other bird.

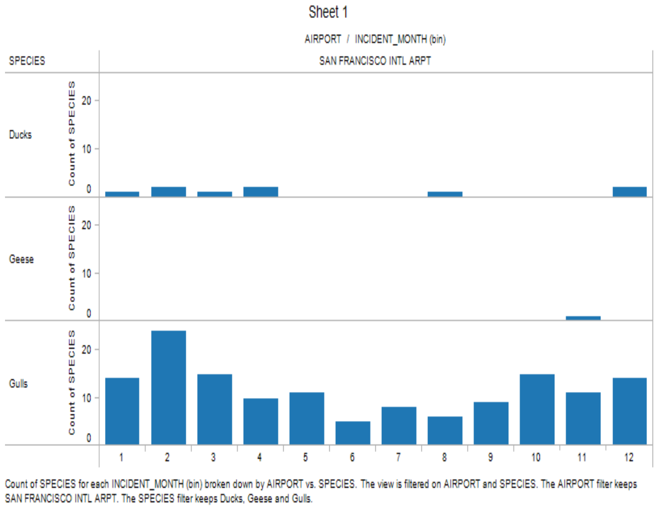

Figure 9: Bird Strikes by month

In Figure 9 it is possible to zoom into details about the month of flight and the kind of bird. The ability to get into details of when the bird strikes happen such as approach vs take off clearly show the dangers during approach, especially from sea gulls. During the migratory seasons the pilot should keep a close eye during the approach.

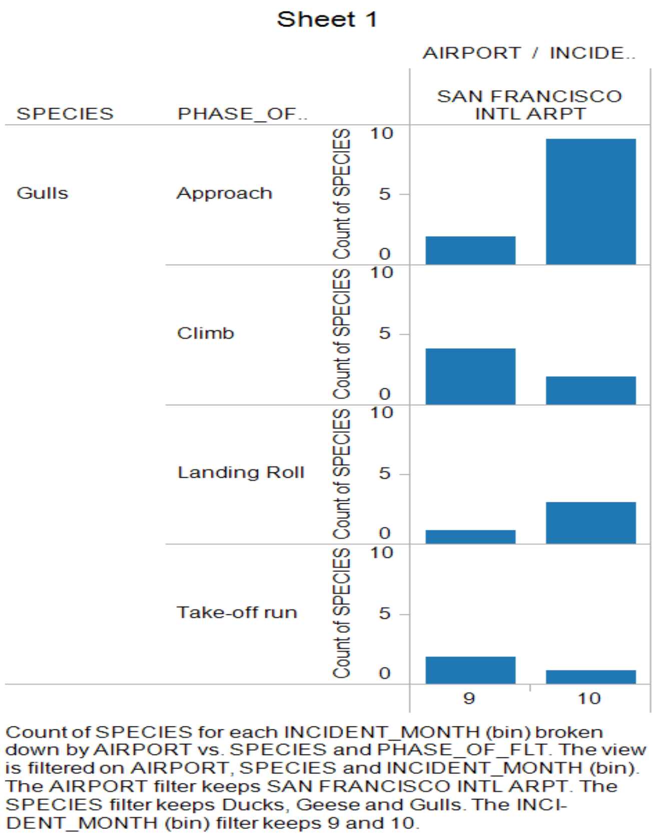

Figure 10. Bird Strikes during different phases of Aircraft flight in San Francisco.

Figure 11 shows the visualization of the migratory patterns of the birds. This show the paths the pilots may choose to avoid or keep a lookout for during peak migratory seasons.

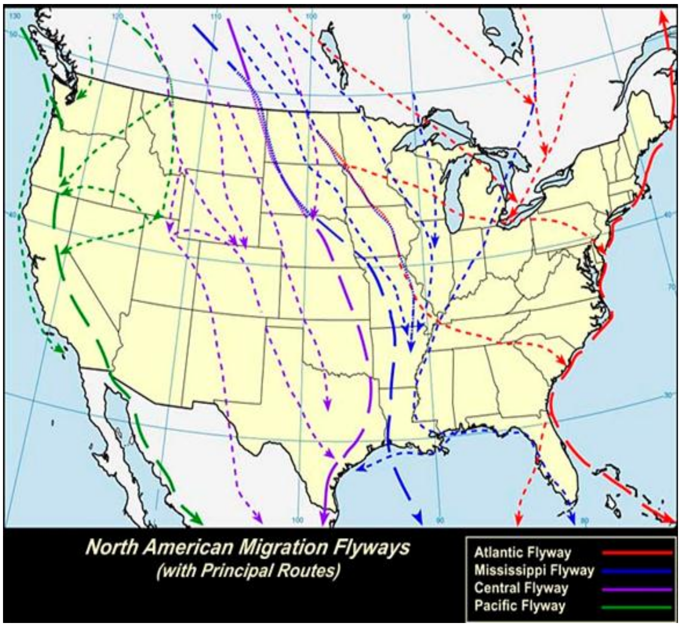

Figure 11. Principal routes of the bids paths

4.2 Conclusion on using Tableau

The ability to zoom into details on demand is very useful. The visualization of the migratory patterns of the birds enables the pilots to avoid high-risk paths. Details provide additional information that allows pilots to be more cautious during the stages of the flight with the highest risk of a bird strike.

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