Improving Airplane Safety: Tableau and Bird Strikes

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Abstract

Safety engineers at Boeing are faced with an increasing amount of data containing aviation safety related events. This is both a gift and a curse. Additional data paint a more comprehensive picture of aviation safety-related events, but analyzing records and identifying particularly important events becomes extremely time-consuming. The FAA's National Wildlife Strike Database (NWSDB) is a growing database containing records related to bird and other wildlife strikes with planes. Tableau was applied to the NWSDB using a paired analysis approach to analyze bird strike data more efficiently. With the paired analysis approach, a subject matter expert (SME) in aviation safety at Boeing worked in conjunction with a visual analytics tool expert (TE) to visualize bird strike data. The ability to visually explore and interact with this data proved useful and has helped to change how safety analysts think about their data.

Keywords: Visual Analytics, Tableau, Paired Analysis, Boeing, Kinetic Energy, Search Process, Evaluation/methodology

Index Terms: H.5.3 [Group and Organization Interfaces]: Computer-supported cooperative work

1 Introduction

Current methods of analyzing airplane safety-related data involve significant amounts of processing, querying and reading. Excel is widely used to examine records that have been generated from in-house queries on safety databases. It often takes a very long time to find records of interest, as the query generation process is very iterative and the current method of validation involves reading individual records within Excel. In fieldwork performed before the paired analysis sessions, it was determined that the field of Visual Analytics was a promising approach for analyzing airplane safety-related data. During a three-month internship at Boeing, Tableau was used on aviation safety data while working with airplane safety engineers. One of the tasks was to examine and assess the threat of bird strikes to commercial airplanes, which often included looking at specific areas of strikes on planes. Using the FAA's publicly available National Wildlife Strike Database (NWSDB) [1] and Tableau, visual analytics-based analysis proved useful for a number of assessments. Tableau was a good match for the records in the NWSDB, as the database is largely composed of categorical and numerical data. Tableau helped improve the efficiency of searching for relevant events in the cases of kinetic energy, species and location of damage.

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2 Paired Analysis

Paired Analysis (PA) is a collaborative method of analysis involving a subject matter expert (SME) and a Visual Analytics tool expert (TE). The PA approach has been influenced by existing techniques from multiple domains. One influence is a technique that appeared in the software development world called extreme programming [2]. Also known as pair programming, extreme programming involves two programmers developing software side-by-side at a single computer. The approach was modified so that the two-person model became a TE and SME as opposed to two programmers. The SME's expertise was in aviation safety. The TE's expertise was in the use of several Visual Analytics tools and in methods of pulling data from multiple data sources. Paired Analysis was used to analyze the bird strike hazard to commercial jets using knowledge from both parties. In addition to proving useful for analysis, PA helped the airframe manufacturer assess the value of the visual analytics tool. The collaboration encouraged a think-aloud approach in which both parties learned about the other's expertise while also improving analysis of bird strikes. The paired analysis method allows both the SME to assess the value of Visual Analytics tools for an organization (Boeing) and also illuminates the SME's analysis process for further study by researchers [3].

3 Analysis: Kinetic Energy

Locating the records describing the most damaging strikes is often a top priority during analysis. Without visualization this can require a significant amount of searching and reading of individual records. The amount of damage to a plane caused during a bird strike is generally correlated with the amount of kinetic energy involved in the strike. Unfortunately, kinetic energy is not explicitly stated in the NWSDB. However, the species of the bird involved in the strike and the speed of the aircraft in knots are two fields that usually contain known values.

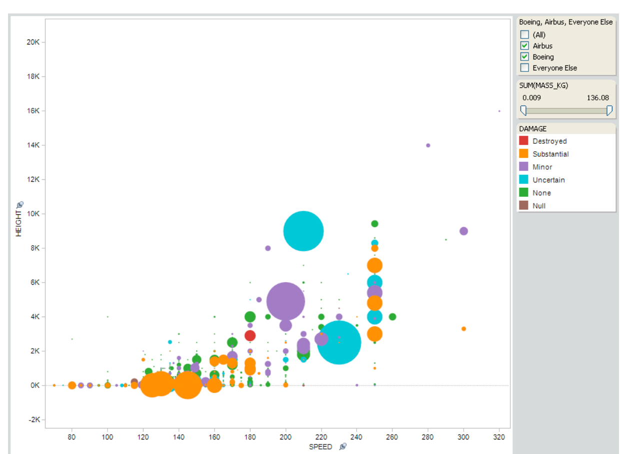

Figure 1. Kinetic energy of bird strikes in the flight envelope. Size represents amount of kinetic energy, color indicates damage to the plane.

By integrating data from additional databases (an average bird weight lookup table) into the NWSDB, kinetic energy can be calculated ($1/2mv^2$). Using Tableau's calculated field feature, a new field for kinetic energy was created in the database. To visualize kinetic energy, we chose to use a scatterplot of strikes in the flight envelope. Figure 1 shows aircraft speed plotted along the x-axis and aircraft height along the y-axis [4]. Each individual dot represents a single wildlife strike. By using the created kinetic energy field for size, the highest energy strikes become visually apparent. In this representation, larger circles represent more kinetic energy involved in the strike. This analysis was also filtered to include only the FAA's most wanted list of species of birds. The "most wanted list" is a list of 12 birds that are frequently struck at US airports and that can have devastating consequences [4].

In Figure 1, the color of the dot represents the damage to the plane resulting from a strike. The interactivity of Tableau and this visualization allowed us to examine the strikes with the highest kinetic energy by mousing over the largest circles. Because kinetic energy is correlated strongly with damage, the most damaging strikes can be located quickly. The SME and TE were able to get an idea of the amount of kinetic energy, altitude of the strike, speed of the aircraft and the species of bird in one quick glance.

Visualizing kinetic energy in this way emphasized its importance in locating strikes of interest. This was a novel approach for using kinetic energy during analysis for safety engineers. The engineers we talked to favored plotting kinetic energy on the flight envelope as an indication of where the strike occurred as well as the total kinetic energy. This type of visualization will be used in the future to plot kinetic energy of bird strikes as well as other safety analyses using the flight envelope.

3.1 Kinetic Energy: Radomes and Windshields

The kinetic energy visualization proved very useful during two specific analyses: radome strikes and windshield strikes. The radome is the covering on the nose of an airplane that protects sensitive equipment like the ILS localizer antenna. Birds striking the radome have the potential to puncture it (and in some cases penetrate fully), damaging equipment like the ILS localizer. We were asked to investigate damaging bird strikes to the radome in an effort to determine whether additional reinforcements were necessary to guard against bird strikes.

By using the kinetic energy plot and Tableau's quick filter for the field of 'DAM_RAD' (damage to the radome) we were able to drill down to only those strikes that had damaged the radome. The largest dots (most kinetic energy) in the visualization were used as a starting point to find the most damaging strikes. This method led us to quickly find most of the strikes where a bird had actually penetrated the radome and eliminated the need to read all of the 'DAM_RAD' records one-by-one.

Further analysis led us to change the color of the dots in the visualization to 'species' rather than 'damage'. By using the color key for species, the visualization allowed the SME and TE to discover which birds were damaging radomes and understand the speed and altitude of the strikes. This turned out to be an efficient way to produce a list of strikes of interest.

Once identified, the penetrating strikes were compiled into a report. The report included the number of penetrating strikes, the species (and average weight), speed of the strike and the timeframe that was observed. From this data the radome group was able to make an assessment of the threat of bird strikes to the radome. They used our analysis to help determine whether additional reinforcements were necessary in the radome. From their testimonials, our method of analysis generated results much faster than the previous method of reading individual reports.

With regard to windshields, a similar approach was taken after a request from one of the windshield design groups at Boeing. Investigating damaging windshield strikes was easy and efficient using Tableau's interactivity and the kinetic energy visualization. We were able to quickly provide a report of the most damaging strikes to windshields without having to read through all the records. The report and analysis was complimented in a similar way to the report for the radome group, citing the speed and accuracy of the visualization in locating damaging strikes. The report also had similar implications for the windshield group: helping them assess the risk of bird strikes and make decisions about whether reinforcing windshields was needed.

4 Analysis: Time of Day and Geographic Location

Eliminating the bird strike risk is impossible as long as birds and planes are both still flying. However, when a flight crew is prepared for bird strikes the risk of serious incident can be greatly reduced. One aspect of bird strike safety involves being aware of the time of day to expect strikes. There are several flight crews who believe that bird strikes are significantly less likely at night. As we demonstrated using Tableau and the wildlife strike data, this is not the case. There is a need for improving flight crew training with regard to dealing with bird strikes.

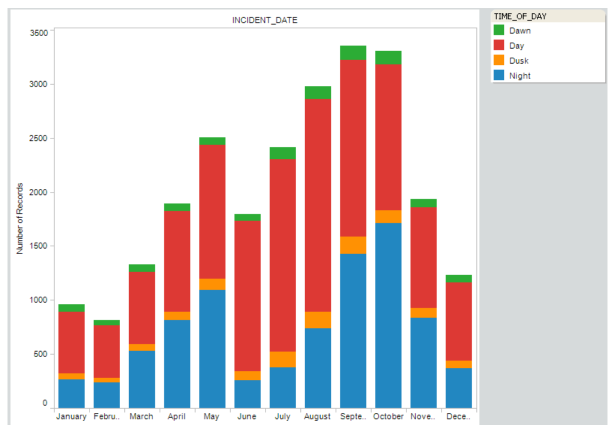

Figure 2. Bird strike distribution by month and time of day, colored by time of day.

The visualization from Tableau shown in Figure 2 illustrates that both the total strikes and the ratios of daytime to nighttime strikes vary from month to month [4]. What is immediately visible is the large portion of strikes at night (the blue bars), particularly during the months of September and October. By interacting with the visualization in Tableau we learned that the total number of nighttime bird strikes actually outnumbers daytime strikes in the month of October.

Using Tableau's quick filters, this visualization was also modified to show the amount of daytime and nighttime strikes in certain regions and even at specific airports. This information is valuable to both airports and flight crews, and the visualization helped the paired analysis understand and communicate the findings.

4.1 Time of Day by Species and Region

Drilling down further into the temporal aspect of bird strikes, individual species can be examined for their strike patterns. From previous analyses with kinetic energy [4], it was clear that Canada Geese pose a significant threat to airplanes. These birds are large and strikes result in high-energy collisions and increased damage to the plane. Using Tableau to visualize both the time of day and geographic location was relatively straightforward. The four maps shown in Figure 3 demonstrate where and when Canada Goose strikes are occurring [4]. Each map represents a different time of day: Dawn, Day, Dusk and Night. Larger circles indicate more strikes. The visualization gives an idea of where (and at what

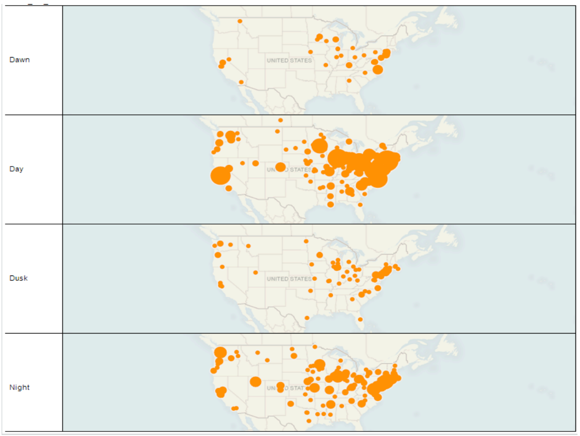

Figure 3. Canada goose strikes by location and time of day. Larger circles represent more strikes at that location.

times throughout a day) Canada Geese are a problem. We can see from the visualization that, on average, Canada Goose strikes occur quite frequently at night throughout the year, though not as often as during the day. By using Tableau to filter and drill down further, it is relatively easy to continue this analysis for specific months, seasons, regions and other species. Much like the bar chart in Figure 2, data about species, location and time of day is very useful to report to airports and flight crews.

5 Summary and Impact: Visualizing Safety Data

Traditionally many airplane safety analyses have involved a significant amount of reading individual records. By using its interactive visualizations, Tableau has proven useful as an exploratory, analytic and communication tool for bird strike data from an airframe manufacturer's perspective.

One important aspect of a safety engineer's daily work is determining what should be considered a 'safety issue'. Safety issues are action items that are dealt with in many ways depending on the nature of the issue. If deemed a safety issue, information such as the frequency of bird strikes during a certain period of the day can be incorporated into flight training manuals. Structural reinforcements and changes to flight training manuals are just a few of the potential outcomes of safety analyses.

Safety engineers are not the only ones determining whether something is in fact a safety issue, and are required to support their assessments when proposing safety issues to managers and supervisors. The safety engineers exposed to visual analytics and Tableau during the internship expressed gratitude for the ease of communicating 'safety issues' using the visualizations in Tableau almost as much as its ability to explore the data and perform analysis. Being able to support an assessment or analysis with a strong visualization improves the likelihood of a safety issue being dealt with in a timely manner. The safety engineers who were exposed to these analyses are continuing to pursue the use of Tableau and other visual analytics tools for bird strikes and other safety concerns.

There is a resolve at Boeing to implement VA tools like Tableau in future work. Since the internship there have been ongoing initiatives to implement these tools throughout safety and reliability organizations. In addition to the specific impact on airplane safety, the bird strike project has already had positive impact in terms of the potential applicability of visual analytics to other Boeing problems. The problems range from project relationship and funding analysis to examination of industrial safety reports in the factory to financial data.

Two factors are contributing to the expansion. First, the quality of the result obtained from visualizing safety data has led to numerous papers and presentations that have exposed hundreds to the power of visual analytics. Second, the advent of paired analysis is pointing the way to ensuring an easier transition of an emerging technology into a larger user community.

References

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