

Visualization of Reported UFO Sightings

Peter Bernstein, Emily Dutile, Abigail Skelton, and Lydia Zakynthinou



Fig. 1. UFOs are “proved beyond reasonable doubt”: A rotating “glowing aura” traveling at high speeds that was captured from a Navy F/A-18 Super Hornet. [6]

Abstract—Reports of unidentified flying objects (*UFOs*) have sparked amateur research, government investigations, and large popular interest in the last five decades. Most reported UFOs are later identified as natural phenomena or conventional objects. However, there is a considerable body of reports about objects that are not identified, which are often rumored as claims of observations of extraterrestrial crafts, raising questions about life on other planets and extraterrestrials visiting Earth. Scientists in their majority have naturally greeted the topic with skepticism but it is widely recognized that answering these questions would be of great importance and a step forward in understanding the universe. We provide an interactive visualization of the reported UFO sightings in the United States in the period of 1910-2014, aiming to help any interested user explore these sightings.

Index Terms—Visualization, Map, Interactivity, Unidentified Flying Object, UFO, United States.

1 INTRODUCTION

An unidentified flying object (UFO) is a perceived object in the sky that is not readily identified. The term UFO (initially, *UFOB*) appeared in 1953 when the United States Air Force used it to describe “any airborne object which by performance, aerodynamic characteristics, or unusual features, does not conform to any presently known aircraft or missile type, or which cannot be positively identified as a familiar object” [4]. Since the 1950s, UFOs have become a major subject of

interest in popular culture and an inspiration for several movies and books [5]. Pop culture has glorified the idea of UFOs, specifically for their perceived link to extraterrestrial life visiting earth.

Although UFOs are largely connected to this theme, it is true that for most of the reported cases the objects are identified to be ordinary or to be caused by natural phenomena after careful investigation. Most commonly, UFOs are identified to actually be astronomical objects, aircrafts, balloons (e.g. weather, research balloons), atmospheric or light phenomena (e.g. clouds, mirages), other atmospheric objects (e.g. birds), or, in some rare cases, hoaxes. The percentage of reports of objects that remain unidentified lies between 5% and 20% [4]. However, there is enough interest and a significant number of reports that cannot be explained by the above occurrences, that the existence of UFOs has garnered both governmental and scientific exploration.

Of the most recently revealed government programs on UFOs is the

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- Emily Dutile and Abigail Skelton are graduate students at Northeastern University. E-mail: {dutile.e, skelton.a}@husky.neu.edu.
 - Peter Bernstein and Lydia Zakynthinou are PhD students at Northeastern University. E-mail: {bernstein.p, zakynthinou.l}@husky.neu.edu.

U.S. Defense Department’s *Advanced Aerospace Threat Identification Program* [6]. The program, which was led by military intelligence official Luis Elizondo, investigated evidence of UFOs and extraterrestrial life from 2007 to 2012, with an annual budget of 22 million dollars. In 2012, the program ended due to changes in the department’s funding priorities, but Elizondo continued his work until October 2017. For him, this is crucially important work and he even contends that UFOs are “proved beyond reasonable doubt” (Fig.1). As for the scientific community, the recent *Breakthrough Listen Program* [7], located in the Astronomy Department of the University of California at Berkeley, is the most scientifically comprehensive search for intelligent extraterrestrial communications in the universe to date [8]. It counts 100 million dollars in funding and gained publicity after the statements of renowned physicist Stephen Hawking on alien life and his support of the program [9].

Though the subject of UFOs is controversial, it deserves and requires research and attention. It is important that there is a general awareness of the subject to the public, so that they might conjecture and discover answers in their own right. To this end, we have created an interactive web-based visualization that allows the public to explore reports of sightings in the United States. It is intended to be visually appealing and give an overview of the reported sightings in the United States throughout the years. It also allows the public to drill down in order to explore characteristics of more specific areas and sightings.

The data we are using is posted on the website of the National UFO Report Center, compiled, edited and maintained by director and sole employee, Peter Davenport. The center’s website provides an online form as well as a phone line for reports of UFO sightings. These reports are annotated by Davenport before they are incorporated into the database. Each report includes the date and time of the sighting, duration, shape, location, date, and description summary, annotated by Davenport as necessary.

Table 1. Data attributes

Term	Type of Variable	Example
Date	quantitative	1/12/10 21:30
City	categorical	Fairbanks
State	categorical	AK
Shape	categorical	Disk
Duration	quantitative	about 1.5 minutes
Summary		“We saw...”
Date Posted	quantitative	1/12/2012

2 RELATED WORKS

Visualizations of the UFO dataset: The dataset we are using has been popular on Kaggle which led two data visualization experts, Pooja Gandhi and Adam Crahen, to use it in their DuoDare project on their DataDuo blog [3]. The DuoDare was a project where each month one of the two experts would choose a data set and call the other on a battle for the best visualization. The two visualizations that the experts came up with for this data set included, among others, interactive maps, area charts, bar charts, and calendar heat-maps. Both visualizations as well as our own include a map of the United States. In Ghandi’s visualization a point on the map corresponds to an area and hovering over the point shows a moving tool tip of the number of sightings that have been reported in that area. In Crahen’s visualization each point corresponds to a single sighting and hovering over the point shows the details of the sighting. Crahen’s visualization includes a calendar heat-map, which also allows the user to click on a particular year/month/weekday/hour and filter the sightings she sees. Ghandi’s visualization includes an area chart of the number of sightings through the years and allows the user to filter the data over time by hovering over a particular vertical line on the area chart. This action also updates a donut chart showing the number of sightings in that year as a percentage over the total number

of sightings. In addition to these, it includes two horizontal bar charts showing the five locations/shapes with the highest number of sightings, as well as two visualizations regarding the top five countries besides the United States with the highest number of sightings.

In our visualization, we use the same encoding as Crahen for the overview task, i.e. we use a map where each point corresponds to a sighting. However, instead of showing a static map of all the points, we allow the user to select the year of data shown, using the interactive time slider. Our area graph visualization allows the user to explore more patterns of sightings over the years, whereas the other two visualizations only use filtering to allow the user to explore these patterns. As an extra overview feature, we color each state based on the number of sightings that have occurred in that state. In addition, our visualization is different from the other two as it supports drilling down into the data. It allows the user to click directly on the map to zoom in and see more clearly the sightings in a smaller area. Finally, our visualization allows the user to brush over an area in the scatter plot of states, thus selecting a group of sightings, updated the donut chart to show percentage of each shape seen, and showing the user in text which states are selected. We believe that this additional exploration based on the state and specific area is more intriguing and would make the visualization more interesting and enjoyable to the user. We base this on the fact that our visualization supports the task of “What sightings have happened in my area?” which provides proximity and individualization to the project.

Visualizing geographic spatial data: Since we have geographic spatial data, we chose a map to represent the data points. There are several types of maps, based on the type of surface the Earth is projected on. There are three main types of projections: cylindrical, conical, and azimuthal [10]. Although cylindrical projections incur a significant amount of distortion ([12]), the Mercator map, which corresponds to a cylindrical projection, is the most commonly used and UX-forward map projection. Since it is more important that the user is familiar with what they are seeing than deriving exact conclusions on the data, we chose to use the Mercator map and would continue to use it for a map of UFO sightings around the world if we had more data. Since we only show a map of the United States rather than the whole world, it doesn’t make a significant difference which projection is used.

3 PROCESS

In this section we focus on the steps that we took to successfully create our project. Many of the steps were prescribed for us beforehand as requirements for the final project for our data visualization course.

Initial data selection: With requirements for a class project already available to us, this dataset became appealing to us for its cleanliness and public availability. The key requirements were that we make an interactive, web-based visualization with at least two different visual encodings and two features from brushing and linking, overview, and details-on-demand. The existing visualizations of this data we found [3] did not incorporate brushing and linking of time with the spatial data, which allowed us to dive in this direction. We felt, that with some modification and improvements upon what currently existed in visualizing this data, we could engage a broad audience that would be able to have fun exploring an interactive visualization of these data.

Interview with field expert: Having decided to use the the National UFO Report Center’s data set for our project, we conducted a phone interview with Davenport to help us better understand the website and data set. The current iteration of the website was established in 1995 and hosts approximately 145,000 sightings, with a noticeable uptick that same year due to the option of using an online form to submit claims of sightings. Currently, there is a weekly UFO update on Coast to Coast AM radio and the website boasts many details with images of suspected sightings. After this interview, we were able to decide which tasks were most important for us to satisfy in our visualization (see 3.1).

Prototyping work flows and refinements to the website based on feedback: Based on the tasks outlined in 3.1, we each created different sketches that we discussed extensively with our team as well as with the teaching staff before incorporating the best features of those sketches

into a final work flow to keep as a goal. Further along the way, there was an interactive feature testing session where we tested a basic D3 prototype of our visualization with our classmates. The feedback we gathered served to help us tailor the design to users less familiar than ourselves. For example, we received feedback to include text that explicitly tells the user how to interact with the visualizations. We noticed that test subjects would sometimes not realize that a feature existed if they were not explicitly told.

3.1 Task Analysis

The main purpose of this project is to serve as a way to explore the data hosted on the National UFO Report Center’s website. The data set hosted there is massive and hard to understand without performing in depth analysis. The domain tasks our visualization supports are in Table 2 and are further explained below.

Table 2. Domain Tasks

Task	Abstraction
Observe how the UFO sightings occur throughout the years	Present
Observe all UFO sightings of a particular year and specific details (such as shape)	Discover
Curiosity stimulation	Enjoy
Look for areas with high number of sightings	Search/Explore
Are there clusters of UFO sightings according to geographic area?	Cluster
Learn details of sighting	Retrieve Value
Did sightings of specific durations have other details in common (eg shape)	Correlate
What states have the most sightings each year?	Find Extremum
What year has the most sightings?	Find Extremum

Observe how UFO sightings occur throughout the years: This task is supported by two visualizations on the webpage. Firstly there is a brushed time-line (shown in figure 2) where you can select a range of years in the lower time-line and see the upper time-line update. This interactivity enables a user to present the overall trend of the number of sightings increasing as reporting became easier and popular culture made more people familiar with the idea that there was a secret conspiracy to suppress news of such sightings.

Additionally, the map of the US allows a user to observe when sightings occur over the years using the slider, and further see their spatial distribution across the country, the duration of the sightings, and the shapes reported.

Observe all UFO sightings of a particular year: The slider above the map enables this task. Just slide the dot to the year desired and then hover the mouse over a sighting to see details. Aggregate details pertaining to that year also appear as before in the scatter plot and aggregate details showing shapes update the donut chart on the right of the map.

Curiosity Stimulation: The webpage is designed in a way to entice a user to read background information and then engage with the interactivity in the visualizations. The overall layout of the website flows like an article with visualizations embedded to give the user perspective before engaging with the tools. There is a small bar chart showing the total number of visualizations by state to give the user a taste of the rest before continuing.

Look for areas with high number of sightings and detect clustering: The map allows the user to search and explore as well as click to zoom in closer on a particular area to examine areas of interest, particularly areas with high numbers of sightings. Since the map shows a point for every reported sightings by geographic area, clusters of sightings per year can easily be detected.

Learn details for sightings: Every point on the map has a tool tip which displays details of a particular sighting when the cursor is held over the point.

Did sightings of specific a duration have other details in common: The brushable scatter plot allows the user to select points with a similar duration and see the donut chart update to show percentage of each categorized shape. The user could notice patterns between the two updating charts.

What states have the most sightings each year: Finding these extrema is simple by using the year slider and the map. Also the initial bar chart at the top of the page shows the states by total number of sightings over the full length of the data set.

What year has the most sightings: To the right of the year slider displays the total number of sightings reported that year. The interactive time line, however, likely is more useful for this task and allows the user to put a years total number of sightings in context with the years before and after it.

4 DESIGN

Our final visualization shows the data in many different ways, all including interactivity to different degrees, which allows the user to decide which path through the story they want to take. When they first load the page, the user greeted by a clean layout, banner, and explanatory text. This serves to make the page seem inviting and encourage the user to read the motivation and explore the tools. Our first visualization is intentionally visible without scrolling, which shows the number of reporting sightings over the history of our data set; this is the highest level of data encoded. The user can hover the mouse over a bar and see a tool tip display the number of sightings in that state in total from 1910-2014.

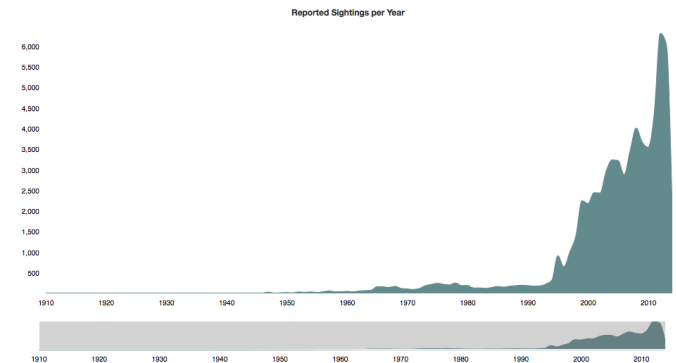


Fig. 2. Interactive timeline of UFO sightings from 1910-2014

After reading what is immediately visible, the user will notice that there is more material cut off at the bottom of the screen. This will lead the user to discover our next interactive feature. The next visualization (Figure 2) shows the reporting sightings per year and allows the user to zoom in and brush the data that they are interested in seeing; there are two ways to brush down the data; on the time series and on the chart itself. If a user is scrolling down the page, they will likely inadvertently discover that scrolling down while the cursor is hovering over the time series chart will cause it to zoom in. This is intended to peak curiosity and allow the user to realize that all the visualizations have an interactive features.

Our final visualization (Figure 4) appears shortly after a little more text, showing the geo-location of each individual sighting during the selected year. The user selects the year using the slider above the map, which populates using points in the exact geo-location for that specific year. The total number of sightings for that year is also displayed on top of the map and the map has an on-click feature, which allows the user to drill down to a state level for more specific information with the data points and ease of access in using the tool tip. The choropleth map is color coded by the number of sightings in a particular state. The shade of purple displayed is the same as the shade in the scatter plot to

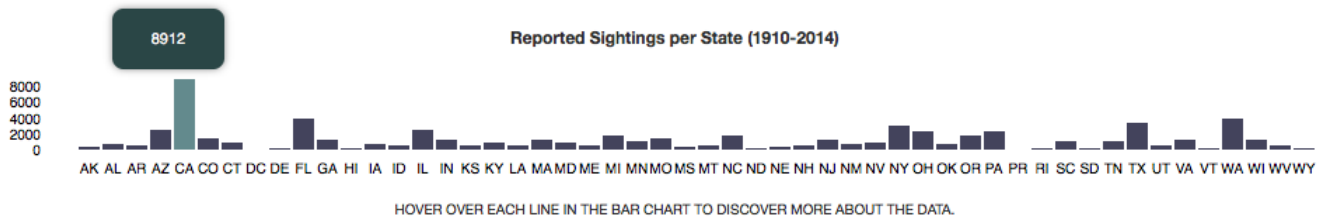


Fig. 3. Interactive bar graph of the total number of sightings by state, with mouse hovering over California

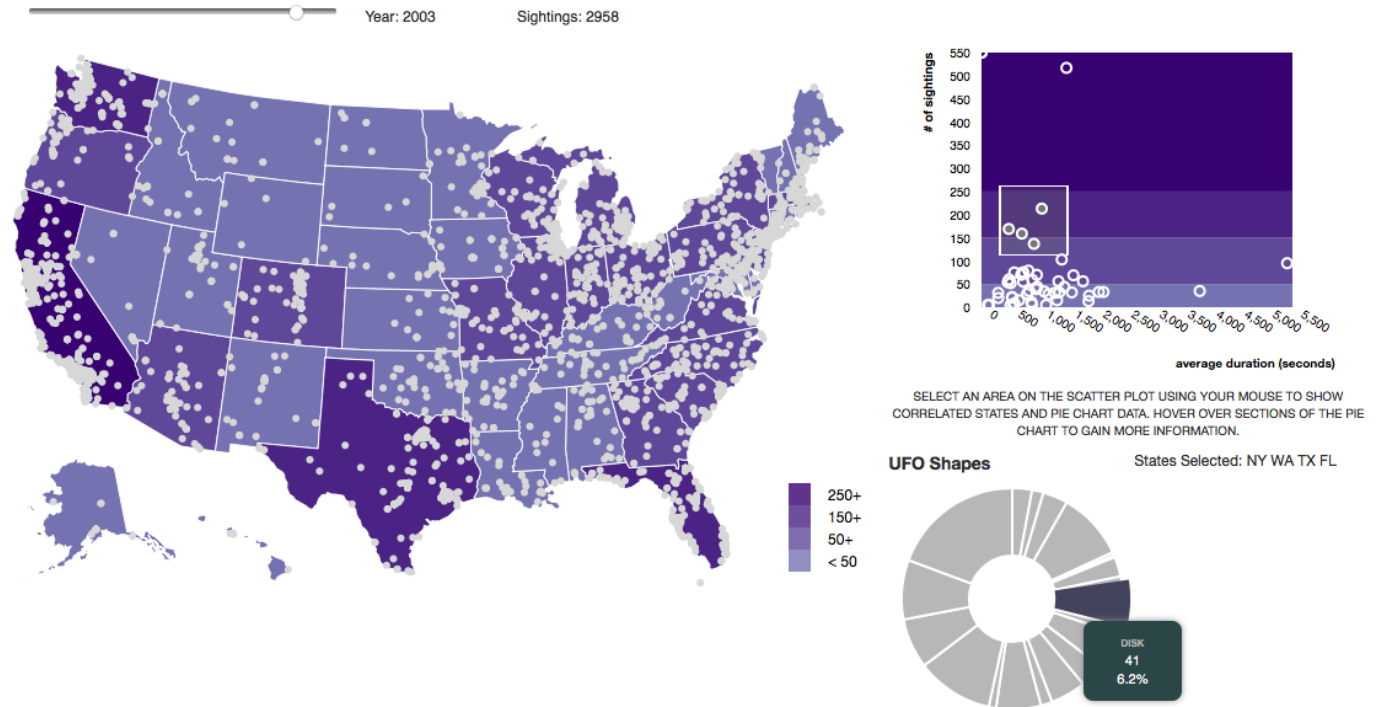


Fig. 4. Interactive national map of sightings with year slider bar and brushable chart of durations and donut chart of shapes of sightings. Mouse is hovering over a sighting in North Dakota and tooltip is displaying

the right, which allows the scatter plot y-axis to serve as a legend for the color, but a more explicit legend is shown at the bottom right of the map that we think is easier to read. That scatter plot displays points that indicate states, and the axes reflect the number of sightings versus average duration. The donut chart shows the proportion of shapes sighted, either by year on a national level, using the brushed data from the scatter plot. A user can also hover over the donut chart to see what shape is represented, as is demonstrated by the tooltip in Figure 4.

This visualization was built using HTML, CSS, JavaScript, and several open-source projects including D3 v4, d3-queue, Moment JS, jQuery, topojson, Underscore JS, Bootstrap, and NodeJs.¹

5 DISCUSSION

5.1 Reflection

The main purpose of this project is to serve as a way to explore the data hosted on the National UFO Report Center's website. The data set hosted there is massive and hard to understand without performing analysis, so any visual representation of the data would be useful to someone interested. Fortunately, the data was extremely well formatted and easy to access and work with. The related work with this data could also be improved with further interactivity and so this project seemed a good fit for our class. Now that it is complete it is clear that

this visualization was an improvement on the existing ones that work with this data set.

An effective method we used to pick our design was study the related work for features that we liked and features we would have liked that were missing. We immediately liked the use of a map and overlaying of the spatial data of the sightings, but due to the large number of points, we were able to know from the beginning that we wanted to incorporate a feature that lets a user zoom in on the map and see sightings over a smaller area. We also decided that the slider at the top to view sightings by year would simplify the data as well, and reflecting on the finished product seems to confirm that it was a good decision.

Looking back at all the initial design sketches, they were overall useful to have done as iterations. We had more than twelve initial design sketches to work off of, and none were constrained by implementation limitations or the actual data. Some of the initial design sketches had a separate window appearing when you clicked on a state, and would display sightings across all years from 1910-2014 on that state. It turned out that it was easy to underestimate the volume of data we would be representing. Combining all the sketches forced us to focus on what limitations we might encounter when implementing an idea. Therefore, we found that creating a single work flow to work towards was valuable in the design phase. It forced all of us to agree upon a single design and make that design more representative of what would be feasible to create in a limited time frame.

¹<https://emily-jean.github.io>

Usability testing was the last milestone before completing development of our visualization. We had classmates from our visualization class test our prototype and studied how they approached the tool as well as solicited feedback from the subjects. This visualization is geared towards users interested in exploring the data, so there is no particular ideal test user. Because of this, we were able to get impactful and varietal feedback during user testing. We decided to include more explicit instructions to users on the website saying that users should click on the map to zoom in and brush points in the lower scatter plot and see the correlated states and pie chart data showing the shapes of the sightings. Without explicit instructions, some users didn't know these features existed or would only discover them after a long time. Since the user testing phase was very easy to conduct, we found the whole process well worth doing and overall helpful.

5.2 Future Work

This paper focused on the UFO data we worked with, the tasks we sought to implement, and the visualization design that resulted from these requirements as well as through acquired feedback. There are many features we would like to be able to include in the future. Among the most interesting would be to associate historical weather data with the dates of the alleged UFO sightings. Additionally, plotting sources of red flags such as airports or weather balloons would be of use in explaining a large number of sightings. The biggest challenge at the moment is acquiring a suitable data set containing this information in a reasonable format.

6 CONCLUSION

We created a web-based interactive visualization providing a novel view of data originally gathered by the National UFO Report Center of thousands of alleged UFO sightings around the country. We incorporated interactivity tools such as brushing and linking to make it easier to dynamically view reported sightings on a United States map and select only reports within years ranges of interest. This allows a map to be less cluttered than existing maps and thus also allows for details-on-demand to be easier to use as there is less ambiguity of where a user is pointing. We used an appealing color palate for the task at hand and created an environment that is amusing and engaging to users interested in understanding the scale of belief in conspiracies or UFOs.

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