# *UFO_Tracker*: Visualizing UFO sightings

***Abstract*—Visualizing and analyzing geospatial and temporal observations are common tasks for many application domains. In this paper, we introduce *UFO_Tracker*, a visual analytics tool for analyzing unidentified flying object sightings from the National UFO Reporting Center. The goal here is to give the user a higher level view of where different types of sightings occur, to investigate whether sightings are increasing or decreasing over time, and to discover the connections between different events which might happen at different geographic areas. Multiple visualization and data mining techniques are combined to make sense the increasingly large UFO reports which get updated hourly. Our initial application targets UFO sighting reports. However, we believe our approach has wider applications in other research domains, such as analyzing text corpus obtained from social media.**

***Keywords–Unidentified Flying Objects, geospatial temporal visualizations, parallel coordinates, dot plots, topic modelings, word clouds, clustering algorithms.***

## I. Introduction

Unidentified Flying Objects, or UFOs, are commonly described as anything that can be seen in the sky but can not be identified as a known object. The story of UFOs began in 1947 in the US [1] when the fast moving, glistening objects were observed from the sky. Inspired by this phenomenon, the National UFO Reporting Center (NUFORC) [2], founded by Robert J. Gribble, has been recording this phenomenon (called UFOs sightings) since 1974 based on user reports. Currently, there are over 100,000 UFOs sightings that have been recorded. Despite over 70 years of observations and 40 years of data collections, the reported evidences are still uncorroborated. Therefore, the rumors of UFO sightings are still interesting over the years: Does the UFO really exist?

Observing UFO occurrences and the rumors about them are valuable for reporting but synthesizing what people are talking about UFOs at specific locations is highly desirable. There is a need to have such a graphical tool that allows scientists to visualize and analyze UFOs in a certain geographic area .

In this paper, we propose a visual analytics tool, called *UFO_Tracker*, that aims for this purpose. The main contributions of this paper are:

- We provide an interactive data analytics tool for visualizing and analyzing a large number of UFOs sightings distributed in certain geographic areas.
- We integrate multiple visualization and data mining techniques, such as parallel coordinates, dot plots, word clouds, and k-means for detecting top key words concerning UFO reports and the correlations between them. This helps UFO scientist to quickly synthesize a large amount of information on UFO sightings.
- We demonstrate our application on the U.S. national UFO reporting center dataset. We also describe interesting UFO reports in the data.

The rest of this paper is organized as follows: We discuss the related work in the next section. Then provide an overview of visualization tasks and describe various components in our system. We discuss our implementation and availability of our tool in Section IV. Finally, we conclude our paper with future plans.

## II. Related Work

This section does not intend to survey all visualization tools for geospatial temporal visualizations [3]. Instead, we discuss some related tools.

### A. Geospatial temporal visualizations

One of the earliest spatial temporal illustration is the Napoleon's march towards Moscow as depicted in Figure 1. The illustration uses position, color, size, and text annotations to captures different states of the Napoleon's army during the Russian campaign in 1812 [4] within a single snapshot.

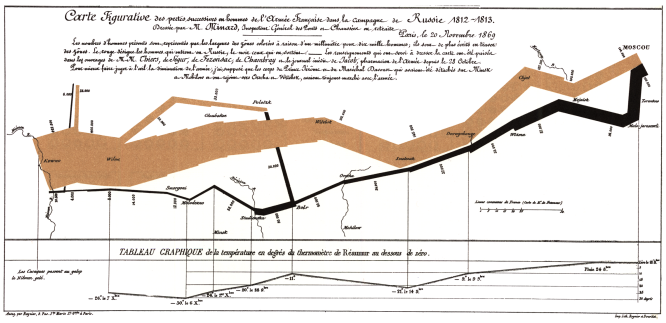



Figure 1. A famous spatial temporal illustration of time flattening [4].

A simple approach to visualize temporal data on a 2D map is to attach the time series graphs directly on top of each geolocation [5]. This easily becomes too clustered for larger time series, especially when geolocations are not equally distributed. Showing summary statistics [6], such as average, standard deviation, or trends [7] on a choropleth map resolves this concern. However, this comes back to the trade-off between details and simplifications.

Using Shneiderman's overview first, zoom and filter, then details-on-demand" metaphor [8], CrimeViz [9] combines with mashup techniques to integrate additional visual elements on top of google map for crime analysis. Similarly, Ramakrishna *et al.* [10] present another software mashup which can handle a large spatio-temporal data set with 2.5 million records using hexagon binning.

### B. UFOs sightings visualizations

There have been various available tools for visualizing the occurrences of UFOs sightings over the last decades. Sam Monfort [11] has created an online heat map of data from the National UFO Reporting Center (NUFORC). This graphical tool renders aggregated data since 1905 through line chart and heat map but this tool is limited to static images. Mutual UFO

Network (MUFO) [12], located in CA, is the oldest non-profit organization that investigate the reported UFO sightings, its tool, UFO Stalker, allows users to view the trending statistics of sightings, along with the filter function that narrows down cases within period of time. Max Galka created an interactive visualization UFO sightings map [13] that clusters users' reports based on geographic location. However, none of these available tools are able to synthesize information based on the users' reports.

In this paper, we provide an interactive data analytics tool for visualizing and analyzing a large number of UFOs sightings distributed on certain geographic areas and integrate parallel coordinate feature for detecting top key words concerning UFO reports

## III. *UFO_Tracker* VISUALIZATIONS

*UFO_Tracker* is a visual analytics tool that gives the user a higher level view of where different types of sightings occur, investigates whether sightings are increasing or decreasing over time [6], and discovers the correlations between different events. This tool also supports filtering the popular terms of reports across regions based on user selections. Finally, it allows analysts to compare report cases across different areas and over time.

This section explains *UFO_Tracker* components in detail.

1) **Processing input datasets:** We obtain the data from the National UFO Reporting Center [2]. Then we calculate the distribution of UFO sighting over years, dates in a month, and hours in a day. (see Section III-A)
2) **Visualization components:** The visualization contains five main components: the control panel, the google map, the time series sliders, the text cloud, and the parallel coordinates. (see Section III-B)
3) **User interaction:** This part summarizes all possible user interactions using *UFO_Tracker*. (see Section III-C)

Keim *et al.* [14] suggest three step processes for information visualization: overview first, zoom and filter, and then details-on-demand. Moreover, information visualization systems should allow users to perform analysis tasks that largely capture people's activities while employing visual analytics tools for understanding data [15], [16]. The *UFO_Tracker* implements five low-level visualization tasks:

- **T1**: Display overview sighting distributions.
- **T2**: Retrieve and present sighting details on demand.
- **T3**: Cluster sightings based on their geolocations.
- **T4**: Show trends or patterns of sightings over time.
- **T5**: Filter and sort sightings by user interests [17].
- **T6**: Find the correlations between different sightings.
- **T7**: Detect anomalies or suspicious sightings.

### A. Processing input datasets

We will demonstrate *UFO_Tracker* on UFO sighting data from the National UFO Reporting Center [2] in the contiguous US from January 2001 through December 2010, which is about 35 MB of data (with 25,559 sighting reports). We also try to find the correlations between UFO sightings with the airport locations available at [18], military bases available at [19], and population density available at [20].

Figure 2 gives quick overview of UFO sightings statistics over the 2000s: (a) sighting distribution by population densities, (b) sighting distribution by distance to the nearest airport (or military base), (c) sighting distribution by year (from 2001 to 2010) (d) sighting distribution by month (from January to December), and (e) sighting distribution by hours of a day. Here are our observations from the graphs in Figure 2:

(a) Most of sightings are reported in urban areas (with high population density).
(b) Sightings are frequently observed nearby airports.
(c) The year of 2008 is the most sighted year in the 2000s.
(d) July is the most sighted month in a year.
(e) Most of sightings are observed and reported at night, especially right before midnight.

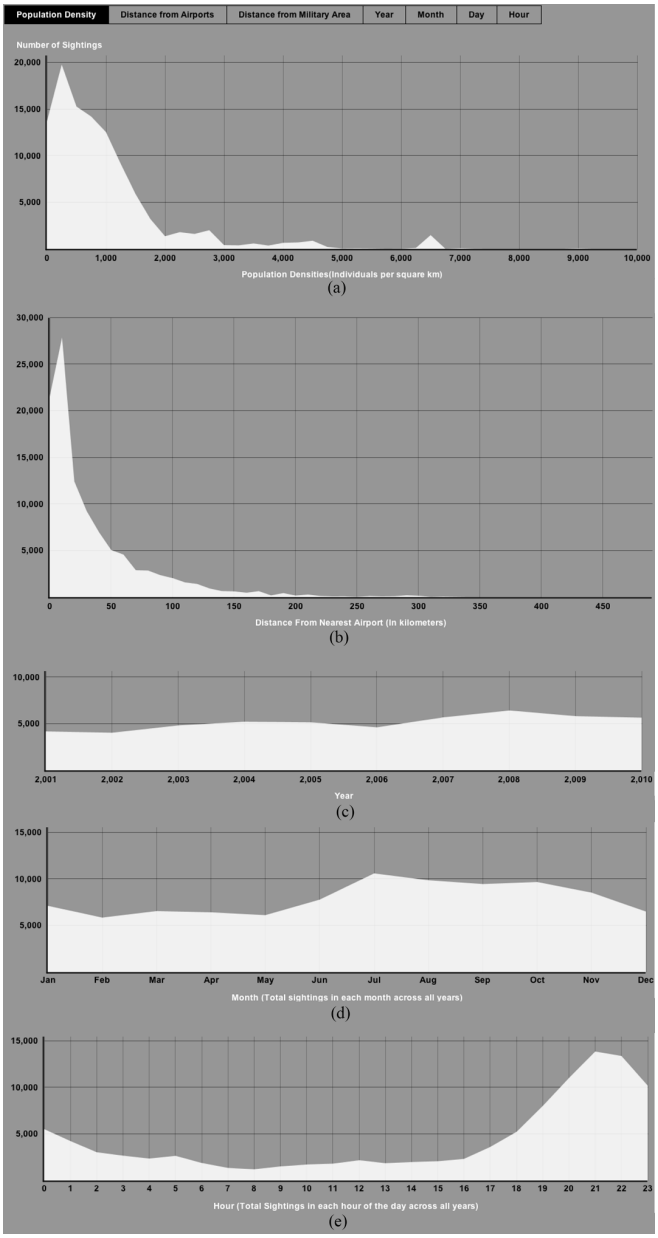



Figure 2. Correlations between the number of sightings and other variables, such as population density, distance from the nearest airport/military base, years in the 2000s, months in a year, days in a week, and hours in a day.

### B. *UFO_Tracker overview*

The input data is expanded in the following dimensions: time, geolocation, and text. Exploring the connections between theses dimensions is challenging. In this application, we apply multiple visualization techniques to highlight individual dimensions as well as the relationship between them. Figure 3 shows the main GUI of our visual analytics tool which is implemented Processing [21] and Java. Box A contains the control panel (or list of options provided to users). Box B displays the google map where each UFO report is displayed as a circle. Google-map navigation capabilities, such as zooming in/out and panning are supported. Box C shows the top keywords extracted from user descriptions of the UF0 reports selected on the map. Finally, Box D contains the time series filters (range sliders).

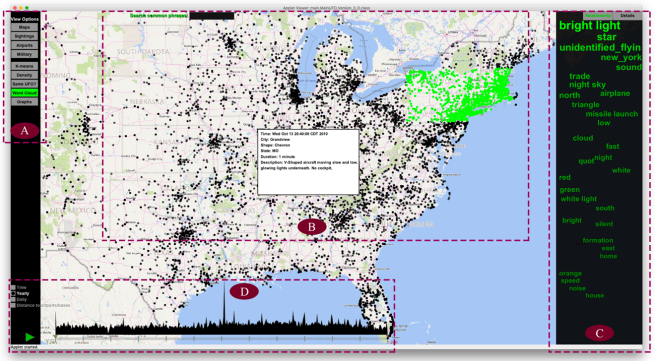



Figure 3. Main interface of *UFO_Tracker* visualization: a) Control panel b) Google map c) Text cloud d) Time series slider.

**The Google map** Within this map, each black circle represents an UFO sighting (visualization task **T1**). Mousing over the circles, users can view the report details (on a popup window), such as timestamp of the sighting, city, state, shape, duration, and description (as shown in Box B of Figure 3). This meets the visualization task **T2** requirement.

**The heat map** When there are too many sightings on the map, overlappings are unavoidable. Users have an option to switch to the density (heat) map. In particular, we apply a kernel smooth density estimation in order to produce an high-level overview of the sighting distributions (visualization task **T1**). Brighter color illustrates areas with more sightings. As depicted in Figure 4, there are many UFO sightings reported in San Diego.

**The airport and military bases** Airplanes and military experiments are the most mistaken for UFOs [22]. All US airports and military bases can be plotted on the map on demand so that users can visualize and analyze the correlations of them and UF0 sightings. Figure 5 shows only sightings reported near airports and military bases.

**The k-mean clustering** *UFO_Tracker* clusters UFO sightings based on their geographic locations using k-means [23] (visualization task **T3**). Figure 6 shows an example of k-means clustering for 20 clusters (encoded in colors). The white circles are centers of these 20 clusters. As depicted, more clusters are formed on the East half of US.

**The time series graphs** Time series visualizations have been commonly used to show chronological distributions of geospatial data in which time is represented in horizontal axis and a statistical variable in vertical axis [24]–[27]. In *UFO_Tracker*, we use area graphs to show the sighting frequency over years, days in a year, and hours in a day. These graphs show patterns and trends of the number of user reports over time (visualization task **T4**).

A range slider is implemented for each distribution graph which allows users to easily narrow down the time interval of interests (visualization task **T5**). In Figure 7(a), we filter the sightings which are at least 50 miles from the nearest airport/military base, from 9pm to midnight, and from September 2005 to July 2009. In the top (time) filter, we create double-layer sliders. The lower slider shows monthly frequency of

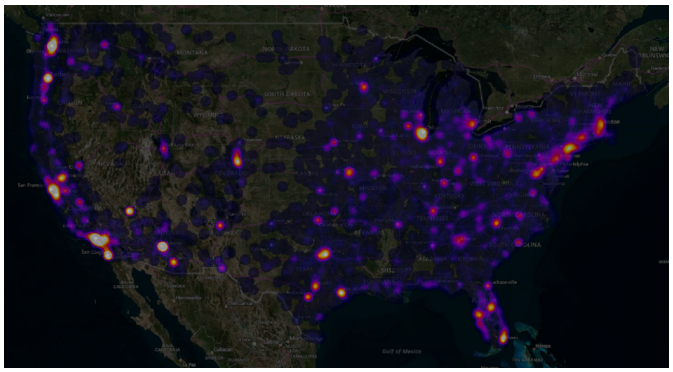


Figure 4. Kernel density heat map in *UFO_Tracker*.


Figure 5. UFO sightings within 50 miles to the nearest airport and military bases.

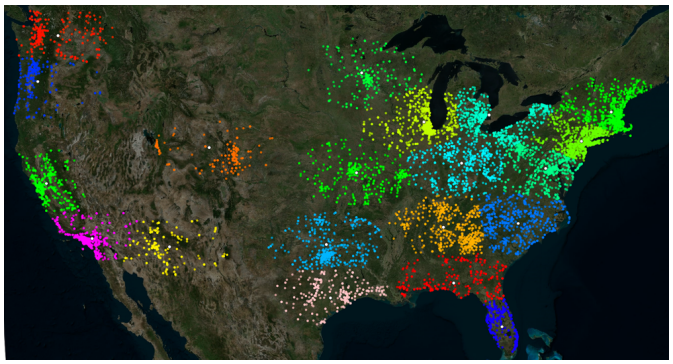
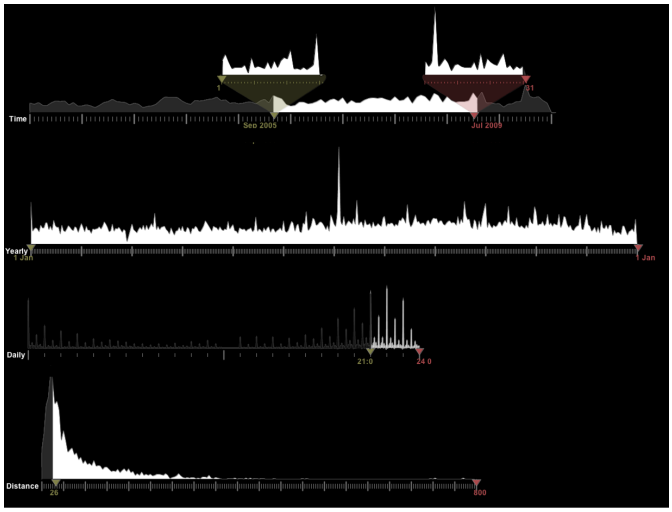
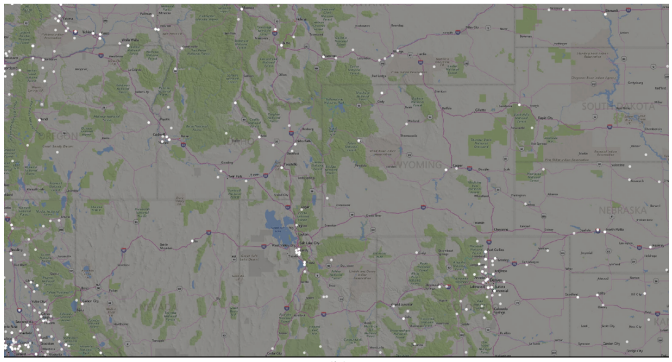


Figure 6. K-means clusters of UFO sightings based on their geographical locations.

sightings. The upper two sliders show daily frequency of September 2005 (yellow, on the left) and July 2009 (red, on the right).




(a)



(b)

Figure 7. The time series graphs show the trends of sightings. Data can be filtered by moving the range sliders along the charts. White bands in the middle of the range sliders are the filtered areas.

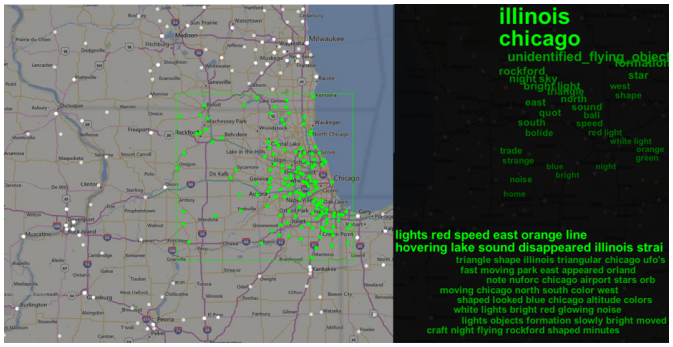
As depicted in Figure 7(b), most of sightings are reported in rural areas close to the big US highways, as an indication that these UFOs are probably sighted and reported by truck drivers (at night). White bands are the filtered areas.

Besides filtering reports by time intervals, *UFO_Tracker* also supports three other types of filtering:

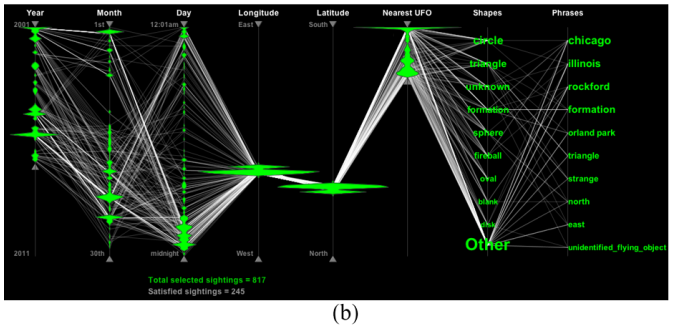
- By inputting term into a search box, such as "aliens" or "abduction', relevant sighting (contain the search terms in their report descriptions) are highlighted.
- By rectangle selection on the map using mouse drags.
- By nearest sightings: if there are other sightings close in locations and times.

Further text analytics inspections on the selected sighting are described next. As our color convention in this paper, white is used for available sightings on the map while green highlights selected sightings based on one of the three approaches listed above.

**The text analytics**




(a)

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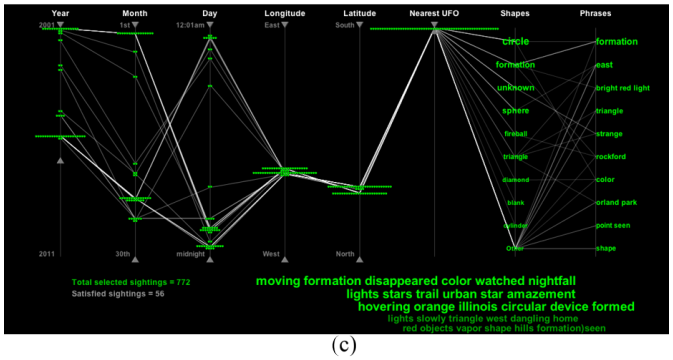


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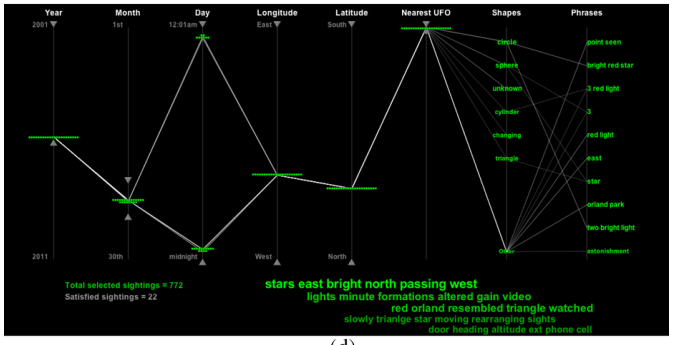
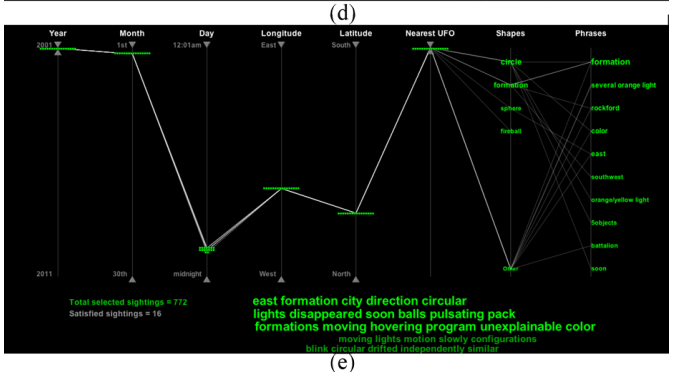



(d)




(e)

Figure 8. Visualizing texts in *UFO_Tracker*: (a) The most frequent keywords/topics (extracted from LDA algorithm [28]) (b) parallel coordinates (c) dot plots [29] on each dimension (d) UFO sightings at Rockford, Illinois in January 2001 (e) UFO sightings at Tinley park, Illinois in October 2004.

We are usually curious in not only the sighting locations, times, or shapes of the sightings but also what people said about the scenes they observed. Our text analytics window provides users a summary of topics in extracted from the large corpus of sighting descriptions. Two options for text visualization include popular terms and popular topics. Popular topics are extracted using Latent Dirichlet Allocation (LDA) [28] method along with Java-based topic modeling package [30].

The right panel of Figure 8(a) shows the top 30 keywords (top right) and the top 10 topics (bottom right) for the selected sightings in Chicago land using rectangle selection (the green box). The more frequent keywords/topics are larger, brighter, and appearing on top the word/topic clouds. Each LDA topic contains the 6 most frequent terms (not a complete sentence). When users mouse over a keyword/topic, the subset of (green) sightings containing this keyword/topic is highlighted on the google map (visualization task **T6**).

Users can now explore correlations between sightings in a customized parallel coordinates.

**Parallel coordinates:** This view categorizes sight features into parallel coordinates as shown in Figure 8(b). The distributions of selected sightings are displayed in smooth area graphs along the coordinates.

Range sliders are available on each dimension to allow users to narrow down their search. In Figure 8(c), we apply filtering on the "Nearest UFO" coordinate. In other words, we want to highlight only UFO scenes which are sighted and reported by different people in the same area and at almost the same time (visualization task **T6**). The time and space dimensions have been standardized and aggregated into a single score, called "Nearest UFO" for each UFO sighting. Notice that the area charts are now replaced by dot plots [29] (every dot is a UFO report). This option is automatically enabled to display a smaller number of selected sightings (less than 100). Consequently, brushing and linking can be done via individual dots (sightings).

Also within this parallel coordinates view, each sighting is represented as a white polyline with lower opacity. Multiple overlapped (similar) sightings create a strong profile which might come from the same UFO scene. Therefore, users can easily spot the correlations between the selected sightings (visualization task **T7**). As depicted in Figure 8(c), we can see two strong cases of UFO sightings: one in January 2001 and another one in October 2004.

Users can narrow down these events individually (using sliders along each dimension) as depicted in Figure 8(d) and (e). The five most important topics extracted from the UFO scene descriptions are also plotted at the bottom. The stories about these UFO sightings in Rockford and Tinley park, Illinois can be found and verified online [31].

### C. User interactions

Interactions on mouse over, mouse clicks, and mouse wheels are provided in *UFO_Tracker*. There are nine options on the left that allows users to view sightings with different aspects as shown in Figure 3 (a). Google map views are available in Aerial, Hybrid, and Road. **Airports** option toggles airport locations on the map. **Military** option toggle all military base positions. **K-means** button clusters UFO sightings based on similarly geographical locations as depicted in Figure 6. **Density** renders density sightings in an area by colours. Figure 4 illustrates the density of sightings through heat map. **Same UFO?** gives information about similar observed sightings spanning throughout the nation. **Word Cloud** [32] option allows users to select multiple sightings and text analytics window highlights the top keywords/topics corresponding to the chosen sightings. **Graphs** option displays the correlations between the number of sightings to different attributes such as population density, distance from airports, distance from military area, year, month, day, and hour.

**Details:** This option provides detailed information about the selected sightings such as time of occurrence, city, shape and description. It also highlights keywords corresponding to each sighting as shown in Figure 9(b).

## IV. Implementation

*UFO_Tracker* is implemented in Processing [21] and Java. The open source code, video, and project documentation are available on our Github repository at https://github.com/iDataVisualizationLab/UFO.

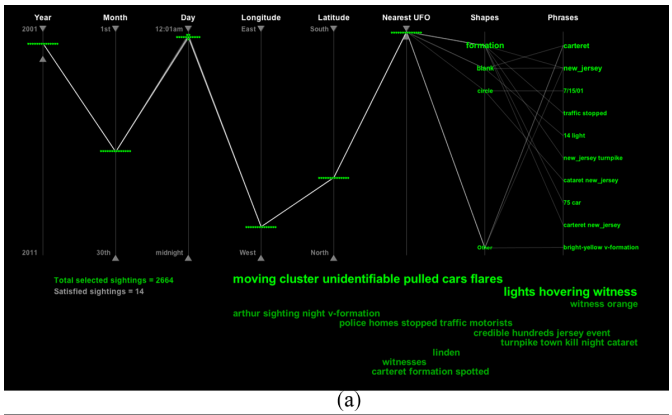
## V. Case study

To demonstrate the usefulness and effectiveness of the *UFO_Tracker* visualization. We observed a non-expert in ufology to use this tool to explore sighting data and observed his actions. The user first explored the view options to familiar himself with different graph layouts. Then he played with some data on the google map, such as zooming, panning, and selecting data. He then read detailed information about specific sighting by mouse over some sightings in New York, Washington, California, and rare cases in the Dakotas. The user looked at the time series graph and moved sliders to left/right directions to see how the distribution of sightings changes. The user found that many UFO sightings were reported around 10pm to 1am, on Saturday and Sunday, and in July.

He turned his attention to the word cloud. He selected different areas on google map to see which keywords were popular in each area. Then he further investigated sighting details by clicking on the relationship option to see the parallel coordinates. From there he noticed that some profiles are very dense (thicker white polylines), so he was curious to know more about this phenomenon by using the range sliders. Based on the phrases or top keywords (carteret, new_jersey, 7/15/01, traffic stopped, 14 light, new_jersey turnpike, carteret new_jersey, 75 car, bright-yellow v-formation) along with the shapes information as depicted in Figure 9(a).

He discovered that these keywords can be generally interpreted as "There were 14 bright-yellow lights on the sky, mostly in unknown shape, at Turnpike road, Carteret, New Jersey on 15 July 2001. All traffic stopped, around 75 cars at this location to witness this event". In order to validate the inferred sentence, he made a google search to find this sighting events (as depicted in Figure 10) . It was very interesting that this inferred sentence not only provides accurate information but also gives additional detail about the event [33].

Due to the limited space of the paper, we advise viewers to see more UFO stories and findings using *UFO_Tracker* on our Github repository available at https://github.com/iDataVisualizationLab/UFO.




(a)

| Time | City | Shape | Duration | Description |
|---|---|---|---|---|
| 2001-07-15 00:15 | Carteret,NJ | Formation | ? | v-type formations and more, hovering, then fading out one by one. |
| 2001-07-15 00:25 | Carteret,NJ | Other | 20 Minutes | ufo spotted over carteret, linden, woodbridge. |
| 2001-07-15 00:29 | Carteret,NJ | Circle | 2 Minutes | 25 lights, 75 witnesses over cataret nj on 7/15/01. |
| 2001-07-15 00:30 | Carteret,NJ | Formation | 15 minutes? | slow moving v-formation of lights with orange flares. 75 cars pulled over on nj turnpike at night |
| 2001-07-15 00:30 | Carteret,NJ | BLANK | 10 MINUTES | lights over new jersey |
| 2001-07-15 00:30 | Carteret,NJ | Light | 20 min | massive nj sighting |
| 2001-07-15 00:30 | Carteret,NJ | Other | 15 mins | strange lights over carteret |
| 2001-07-15 00:30 | Carteret,NJ | Formation | UNKNOWN | moving light formation |
| 2001-07-15 00:38 | Carteret,NJ | Formation | minutes | major sighting by hundreds motorists along the nj turnpike (traffic stopped!), from homes |
| 2001-07-15 00:38 | Carteret,NJ | Light | 1 hour | bright lights in sky, unidentifiable! |
| 2001-07-15 00:40 | Carteret,NJ | Formation | BLANK | orange lights hovering over carteret nj in v formation |
| 2001-07-15 00:40 | Carteret,NJ | Light | unknown | bright-yellow v-formation spotted in the the night sky over the arthur kill |
| 2001-07-15 00:40 | Carteret,NJ | Light | BLANK | flickering golden lights in nj |
| 2001-07-15 00:45 | Carteret,NJ | BLANK | BLANK | forwarded report: credible witness describes cluster of 14 lights moving over town of carteret, nj. |

(b)

Figure 9. Filtering on parallel coordinate to uncover the UFO scence happened at 12:15 AM, 15 July 2001 at Turnpike road, Carteret, New Jersey: (a) There were 14 reports (green dots on each dimension) recorded for this event (b) The details of these reports are displayed on demand.


Figure 10. A youtube screenshot of the UFO formation on July 15, 2001 at Turnpike road, Carteret, New Jersey [34]. This picture is captured when the user tried to find relevant resources on the internet based on the finding in Figure 9(a).

## VI. Conclusion and Future Work

Investigating UFOs sightings is an ongoing challenge and ultimately an interesting topic for researchers for discovering the myth of the universe. In this paper, we introduced *UFO_Tracker* as a graphical tool that allows researchers, especially in the field of ufology, to gain a better understanding about UFO sightings based on geographic locations, and aggregated top keywords in a given area.

This tool is not limited to UFO sighting discovery but have more general applications on many different areas (which require to analyze the data on the following dimensions: time, geospatial, and text analysis) such as disease spreads, rumor tweets, and political blogs. This is one of the future direction of this work.

In another future work, we are planning to introduce topic recommendations into our application (the complete inferred sentence extracted from top topics). This new direction is very promising since it helps ufologists and scientists grasp deeper level of knowledge on UFO sightings.

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