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EpidNews: An Epidemiological News Explorer for Monitoring Animal Diseases

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ABSTRACT

In the recent years, there has been a massive increase in the amount of data being produced about human and animal health related events. Epidemiologists have to analyze this epidemiological data on a regular basis. They use this spatio-temporal information, most of which is shared online, to detect, observe, and track geographic locations of disease outbreaks over time. Unfortunately, manually retrieving the data from a website like Google News and then deriving sensible insights from the huge dataset consumes a lot of time and effort. We present *EpidNews*, a new visual analytics tool that helps to visualize and explore epidemiological news data for animals. The tool uses several views depicting various levels of abstraction, which helps fulfill almost all the data analysis requirements of epidemiologists. We also present the case study of an epidemiology expert, wherein she assesses the usability and productivity of *EpidNews* by using the tool in her daily work.

CCS CONCEPTS

• **Human-centered computing** → **Visual analytics**; • **Applied computing** → **Health care information systems**;

KEYWORDS

Animal epidemiology, spatio-temporal information, visual analytics

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1 INTRODUCTION

There exists a large amount of data on human & animal disease outbreaks on digital media. However, in this paper, we have focused our work on animal diseases - tracking of which is important to prevent unwanted animal deaths. Animals play a key role in human activities such as agriculture & poultry. Also, there is a constant risk that animal diseases can be transmitted to humans (zoonosis).

A significant amount of effort in epidemiology research goes into detecting, observing, and simulating disease outbreaks. The epidemiologist's aim is to prevent the diseases from spreading, for which they need to collect and study large amount of information from online news sources. Traditionally, epidemiologists have relied upon the internationally accepted official sources, like the World Organization for Animal Health (OIE) and the Animal Disease Notification System (ADNS) for obtaining the data. The European Food Safety Authority (EFSA), for example, used the ADNS notifications to highlight how the *African swine fever virus* which was initially reported in the Baltic countries in 2014, spread to the eastern parts of Poland, causing *wild boars* deaths in large numbers [9]. The data from these official sources is directly available in a well-defined format i.e. with proper tagging of epidemiological clues like *diseases*, *hosts*, *dates* and *locations*.

Moreover, several platforms dedicated to automatic surveillance of electronic media have been developed over the past two decades [6]. Contrary to the official sources, the data from such web reports is not structured and therefore, the epidemiological clues (*diseases*, *hosts*, *symptoms*, *dates* and *locations*) are extracted by data mining techniques [3] - we refer data obtained from such techniques as 'unofficial'. It is important to note that both the sources are valuable for the epidemiologists: the official ones because they contain validated information about the diseases, and unofficial ones because they are usually published well in advance of the official ones - providing early insights of new outbreaks.

Analyzing this complex heterogeneous data is a daunting task without the use of a dedicated tool. Visual analytics is a domain that

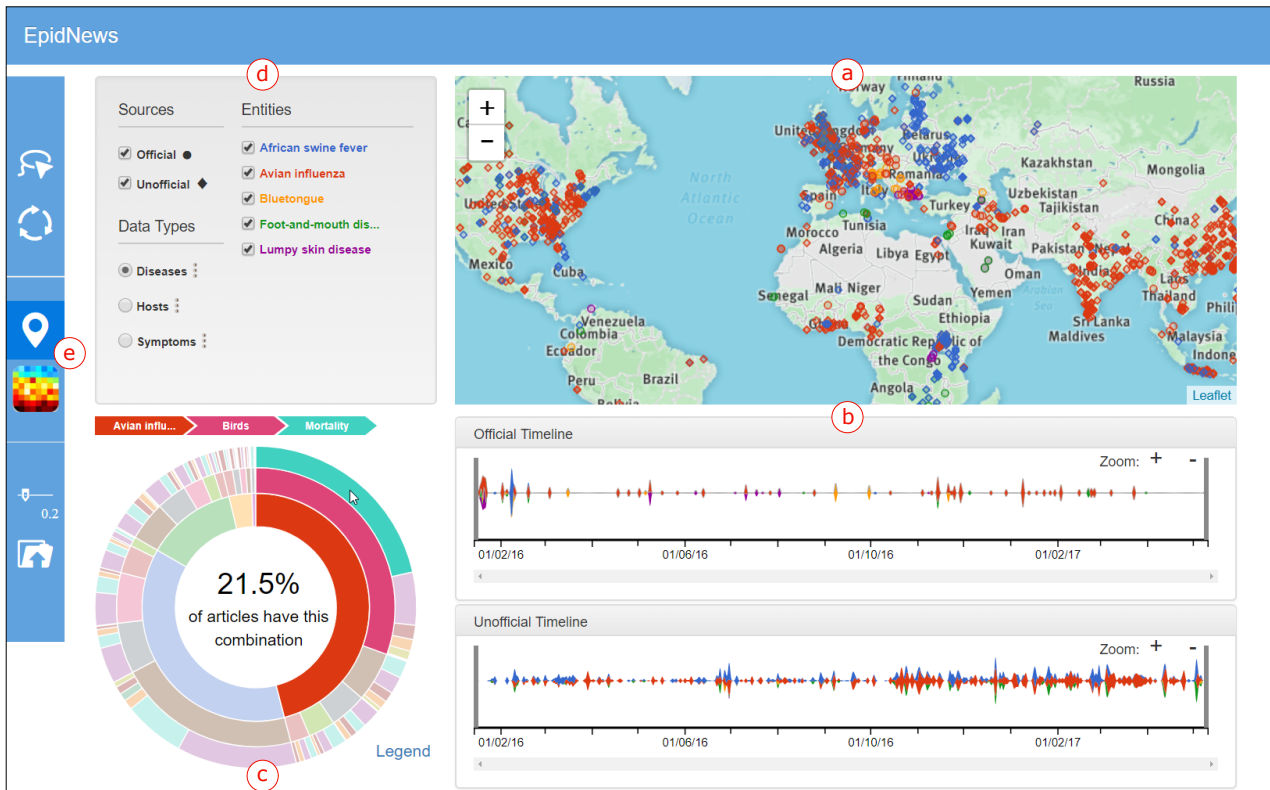


Figure 1: An overview of the tool *EpidNews*. (a) Map shows disease outbreak locations using a circle or diamond depending on source type. (b) Streamgraphs compare the time evolution of official and unofficial sources. (c) Sunburst presents relationships between diseases, hosts and symptoms in a hierarchical view. (d) Data manager allows manipulation of the data represented in the other views (sources, data type and entities). (e) Toolbar offers other interactive functionalities

focuses on designing visual interfaces to facilitate visual reasoning [8]. In our context, it could provide us with ways to build a tool which will enable us to explore the different aspects of epidemiological news efficiently. Unfortunately, existing visual analytics tools ([7, 12]) do not meet all the requirements of the epidemiologists.

In order to fill this gap, we present *EpidNews* - a new visual analytics tool for epidemiological news data. It provides different views to: (1) handle different news sources (official / unofficial) and data types (*diseases / hosts / symptoms*), (2) visualize geographic and temporal data, and (3) observe data at different levels of aggregation. A demonstration video is available on YouTube¹.

In this paper, Section 2 gives an overview of the related work and Section 3 presents a list of requirements for the tool which were identified by computer scientists in collaboration with an epidemiologist. Section 4 describes *EpidNews* in detail and in Section 5, we present a real world example of the analysis performed by an epidemiologist using *EpidNews* to highlight the benefits of our approach. Finally, we conclude our work in Section 6 of the paper.

2 RELATED WORK

This section first discusses existing techniques in visualizing spatio-temporal data, followed by the various visualization approaches applied in epidemiology.

2.1 Visualizing spatio-temporal information

A piece of spatio-temporal data contains information about both space and time. In [15], Pauquet proposed a triad framework to describe how this can be exploited through three components: where (location), when (time) and what (information). The author also highlights their correlation in the following way:

- **when + where** → **what**: describes the information at a given location and time.
- **when + what** → **where**: shows the location of an information at a given time.
- **where + what** → **when**: gives the time of a particular information at a given location.

Several visualizations have been proposed to represent these components. Generally, the information (what) is combined with the other attributes where, and when. For example, one of the first well-known representation combining location and information was made in the 19th century, by a British physician John Snow,

¹<https://youtu.be/N8yfM42P4ME>

to highlight a cholera outbreak in London [20]. He carried out a statistical analysis of the deaths which highlighted the spread of cholera via water distribution.

Aigner et al. [1]² discusses about the time-oriented visualizations that combine time (when) and the information (what). Such an example is *EventRiver* [13], which represents events as bubbles positioned along the time axis.

Moreover, several visualizations ([5, 11, 17]) combine all the components (where, when and what). The work of Ferreira et al. [11] is one such example, where they propose an interactive visualization combining different 3 views: dot map, scatter plots and timeline.

2.2 Data Visualization in epidemiology

In this subsection, we discuss about the monitoring systems in animal epidemiology. It is important to note that, although some epidemiology visualization approaches have been proposed (e.g., [7, 10, 12, 16, 18]), most of them focus on human diseases and not animal diseases. Existing approaches can track signs of emerging diseases and are based on a formalized process of epidemic intelligence³ [19] focusing on *indicator-based* surveillance (e.g., *Empres-i*, *Atlas*⁴) or *event-based* surveillance (e.g., *HealthMap*, *MedISys*⁵).

Indicator-based surveillance uses structured data collected through traditional monitoring systems like the official outbreak reports of the OIE. For example, *Empres-i*⁶ is a web application that visualizes the information with the help of a map and fetches the data from several sources: OIE, Food and Agriculture Organization of the United Nations (FAO), Government Ministries of Agriculture and Health, etc. Diseases are represented as glyphs on the map to highlight their type (e.g., circles for domestic animal diseases, and triangles for wild animals diseases). It also offers several interactions like choosing time/location by creating a rectangle on the map, along with the ability to save or select data, etc.

Event-based surveillance uses unstructured data collected from heterogeneous sources, such as the web, social networks, field experts, etc. For example, *HealthMap* [12] proposes an interactive map which uses word-processing algorithms from multiple sources like news feeds, expert accounts (e.g. *ProMED-mail*) and multinational monitoring reports, etc. It represents diseases as circles, with noteworthiness of the event being highlighted by a color scale from yellow (minimum value) to purple (maximum value), and the size of the circle reflecting the level of alert. It depicts the disease information over time on a timeline and the geographic distribution as a heatmap. The tool also offers several interactions to filter data by location, time-slices, diseases, species, or sources.

The existing spatio-temporal information visualization tools represent the data using classical charts. For temporal information, representations like a static line chart in *HealthMap*, and a bar chart in *Empres-i* have been used. Furthermore, the spatial information is usually visualized on a static non-interactive map. Unfortunately, these basic visualization techniques don't properly present all the

dimensions of the data. Also, it is important to note that the interactions between these spatial and temporal views are minimal, thereby limiting their usage and effectiveness. Moreover, although these tools use multiple data sources, they fail to separately identify and compare these sources in the visualizations (e.g. *HealthMap*). One can also notice that all of these existing approaches focus only on human related diseases, completely ignoring the animals.

3 REQUIREMENTS

Before developing *EpidNews*, a list of requirements for a tool capable of handling different sources of data (official and unofficial) and the underlying spatio-temporal information were identified through a collaboration between epidemiologists and computer scientists. The requirements identified are as follows:

[R1] Exploring geographical data. This requirement refers to visualizing the news data in the geographic space and generally, the most suitable visualization for this type is a map. The objective is to highlight and observe the different aspects of geographically tagged news data in the same view. By aspects, we mean entities (e.g. the disease *African swine fever*), entity types (i.e. *disease*, *symptom*, and *host*), and news sources (official and unofficial). For instance, an epidemiologist wants to study the spread of the diseases *African swine fever* and *Bluetongue* in France and then compare it to the patterns found in other parts of the world.

[R2] Exploring temporal data. This is required by experts in order to reveal patterns, find peaks and track disease outbreak news over time. For example, epidemiology experts want to observe the evolution of the disease *African swine fever* over the years 2015-2017, and check if the number of news articles referring this disease have increased, decreased or remained the same during this period. Epidemiologists are also keen to know if a disease spikes in a particular month or season of the year.

[R3] Summarizing and filtering data. Very often, the epidemiologists want to visualize a summary and aggregation of the data, in order to easily extract new insights from them. Also the feature of filtering specific data entities is essential in any application. For example, epidemiologists want to know the percentage of articles about the disease *African swine fever* involving a particular host (e.g. *Pig*) and showing specific symptoms (e.g. *Fever*). Also, an expert might want to focus his/her research on only one disease *African swine fever* and would therefore, like to filter away all the other diseases from analysis.

[R4] Interactivity and synchronization. Along with all the above requirements, it is of utmost importance to have synchronization between the different data representations i.e an activity in one, should reflect in the other views too. For instance, suppose that *V1* is a visualization that handles only the time information in data, and *V2* visualizes the location aspect. Now if a user changes the time period of analysis in *V1*, then in order to maintain synchronization, *V2* should visualize only the records falling in that time period. It can be very well noted that this requirement transverses all of R1, R2, and R3. Also, the tool should engage the users by offering various interactions along with the visualizations: like dragging, zooming, ability to update the data, etc.

²timevis.net

³Epidemic intelligence includes all activities related to early detection of health hazards, their verification, assessment, and investigation in order to recommend public health control measures.

⁴<https://ecdc.europa.eu/en/surveillance-atlas-infectious-diseases>, (accessed on March 14, 2018)

⁵<http://medisys.newsbrief.eu>, (accessed on March 14, 2018)

⁶<http://empres-i.fao.org/eipws3g/>, (accessed on March 14, 2018)

4 EPIDNEWS

In this paper, we present *EpidNews* - a visual analytics tool for monitoring the animal epidemiology related news articles. Fulfilling all the requirements, it is composed of several interactive views that allow the users to easily analyze, observe and track the animal disease outbreaks around the world.

Figure 1 presents an overview of the tool. A map (Figure 1.a) shows spatial information [R1] and the two streamgraphs below it (Figure 1.b) visualize the temporal information [R2]. A sunburst (Figure 1.c) presents the relation between different data types, namely *diseases*, *hosts* and *symptoms* [R3] in a hierarchical fashion. Each data type contains a set of entities: for example, the type *diseases* contains *African swine fever*, *Avian Influenza*, *Bluetongue*, *Foot-and-mouth-disease*, etc. A data manager (Figure 1.d) allows the user to select and filter data according to the requirement [R3]. A toolbar (Figure 1.e) enhances the interactivity of all the views and allows uploading new data files. All these components are synchronized to reflect changes and interactions in each other [R4].

4.1 Map

The spatial information [R1] is represented using an interactive map (see Figure 1.a). We propose two kinds of geographical maps: (1) an icon map where each icon/glyph represents a news event which occurred at the corresponding location, and (2) a heatmap showing the distribution & density of the events. The user can toggle between these two type by clicking the third or the fourth button on the toolbar (Figure 1.e). Also each map can be interacted with by zooming in/out and dragging to the required area [R4].

The heatmap (see Figure 2) represents the density of news articles at a particular place. The color scale is from blue (low density), through green, yellow (mid density), to red (high density). For both the map types, the user can filter [R3] a type of source or some particular entities by selecting the corresponding check-boxes in the "Sources" and "Entities" sections of the data manager (see Figure 1.d) - doing which updates all the views simultaneously [R4].

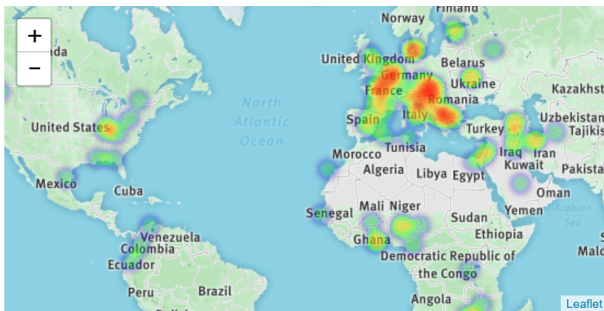


Figure 2: An example of a Heatmap representing the density distribution of diseases from official news sources

The icon map depicts news items with different icons/glyphs: circles for data from official sources and diamonds for the unofficial ones [R1] (see Figure 1.a), thereby making their differentiation easier. Also, the color of glyphs represents and matches the entity (Figure 1.d) contained in that particular news item. For example,

a red colored circle in Figure 1 represents an instance of *Avian influenza* extracted from an official source.

Moreover, in practice, many news articles can occur at the same location which causes overlapping glyphs. The low color opacity of the glyphs helps a user to estimate the number of items at given point by noticing the darkness of colors at that point. For a precise view, the user can click on a glyph, which triggers a pop-up containing the list of all the news items at that location (see Figure 3). Each item of this list mentions the following details: the shape and color of the glyph (signifying the source and entity), the date of the news article, a confidence index (which is a measure of the accuracy with which the location is known), and a hyperlink to the source of the news article.

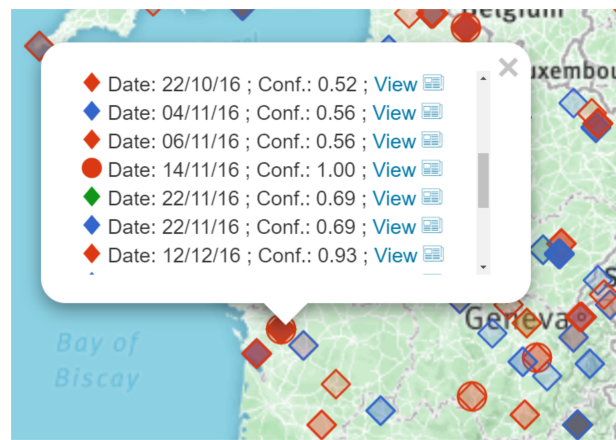


Figure 3: Official (circles) and unofficial (diamonds) news about diseases near Bordeaux, France (*avian influenza* in red, *African swine fever* in blue and *foot and mouth disease* in green)

4.2 Streamgraphs

We represent the time evolution [R2] of the number of news items involving the different entities using streamgraphs [4] (see Figure 1.b). We use two streamgraphs: the top one contains data from official sources and the bottom one from unofficial ones. Markings on the x-axis of both the graphs are placed at same positions to facilitate comparison.

Entity colors are the same as in the data manager and icon-map (see Figure 1.d). Here, again, the user can filter on entity type (hosts / diseases / symptoms) by using the checkboxes. Changing "Sources" has no impact here because the official and unofficial news are already visualized separately.

Since both the streamgraphs are synchronized [R4], hovering the mouse over the streams shows additional information in both of them: the number of entities at the date defined by the x-position of the mouse along with the exact date. This helps in comparing the 2 different news sources over time. For example, in Figure 4, when a user hovers over the streamgraph of official data, labels are displayed in both of them, showing that there were 10 official news items about *Avian influenza* on the 14th of November 2016 whereas

there were only 4 unofficial ones on the same date. One can also observe that the stream hovered upon (here in red - matching the entity color) is also highlighted in both the streamgraphs.

The user can modify the zoom level of a streamgraph by clicking on the dedicated buttons placed conveniently on the top right of each of them. On zooming, the y-axis is not modified but only the x-axis is extended or contracted. A scrollbar at the bottom enables the user to view the parts of the streamgraph which can fall outside the view when zoomed in. Of course, both the scrollbars are synced with each other and also, changing the zoom level in either of them, reflects in both the graphs. Hence, the time period covered by both the streamgraphs always remains the same, thereby avoiding any possible mistake by the user during analysis.

The toolbar (see Figure 1.e) provides another layer of interactivity between the streamgraphs and the map [R4]. The user can activate the lasso functionality by choosing the first option on the toolbar, and then select a custom shaped area on the map. The streamgraphs then show the date of news items in this area using vertical dashed lines, thereby allowing the analysis of spatial and temporal information simultaneously (see Figure 7). Also, the second tool on the toolbar resets the lasso selection.

Finally, two dark gray vertical lines, initially positioned at the left and right ends of the streamgraphs (see Figure 1.b) can be moved to select a specific time period (see Figure 5.b) for analysis. The selected period (lying between those lines) is highlighted, and the data outside this time period is removed from the other views.

4.3 Sunburst

EpidNews summarizes the data by visualizing the hierarchical relationships [R3] between the different types of entities, namely *diseases*, *hosts* and *symptoms* on a sunburst [14]. The view includes three hierarchical levels which correspond to the three data (entity) types. For instance, in Figure 5.c the innermost ring represents *hosts*, the middle ring represents the *symptoms* and the outermost ring represents the *diseases*. The rings are further divided into arcs, each of which represents an entity of the corresponding type. The colors of entities match with the other views: map, streamgraphs and data manager. Users can observe the percentage of different combinations by hovering the mouse over these arcs (entities). For example, Figure 5.c shows that 30% of the news are about *birds* (a *host*), *mortality* (a *symptom*) and *avian influenza* (a *disease*). The user can also click on an entity to filter the data in the other views [R3]. We can also see in Figure 5 that, if a user clicks on the *Avian Influenza's* arc after hovering the mouse over the arcs for *birds*, *mortality*, *Avian Influenza*, the corresponding news items will appear in the map and the streamgraphs, while the others will be removed from the map and faded in the streamgraphs [R4]. Also if a user clicks on *mortality* (i.e. an entity of the middle ring), then the news combining *birds* (innermost ring) and *mortality* will be highlighted, without taking into account any constraints on the entities of the outermost ring, i.e. *diseases*.

The users also have an option of changing the order of the levels in the hierarchy by intuitively dragging the data (entity) types in the data manager [R4] one below/above the other. For example, data types in Figure 1.d and Figure 5.d have a different level order. The sunburst in Figure 1.c is ordered by *diseases* in the innermost

ring, followed by *hosts* in the middle ring and finally *symptoms* in the outermost ring. This basically visualizes different entities of *hosts* for various *diseases*, and also shows the *symptoms* observed in each *host*. Here it helps in identifying which disease affected which host, and what symptoms that particular host showed for that disease. On the other hand the sunburst in Figure 5.c is ordered by *hosts*, then *symptoms*, and finally *diseases*.

As highlighted before: selecting a time period in the streamgraphs (using the two gray vertical lines) changes the data visualized in the sunburst by filtering out the items outside that period.

Finally, we discuss about the two last buttons available in the toolbar (see Figure 1.e). The fifth one can be used to set the minimum confidence [2] for the location of news items i.e news items having location accuracy less the selected value are not visualized on the map. For instance, in Figure 1, all the news items considered have a location confidence of at least 20% (0.2). Moreover, the last button enables the users to upload/change the data for analysis.

5 CASE STUDY: EPIDEMIC INTELLIGENCE FOR MONITORING ANIMAL DISEASES

The objective of this case study is to provide an example where one can use the tool *EpidNews* to effectively monitor the breakout of animal diseases. This example helps highlight the usability and the ease that a visualization tool like *EpidNews* brings to the field of epidemiology, specifically in monitoring the spread of infectious diseases. This case study was performed by an epidemiology expert working in the field of epidemic intelligence. She decided to select *African swine fever* (*ASF*) as the base disease to test this tool since her current research focuses on the same. For the study, the data of official news items is obtained from the *Empres-i*⁷ and *ADNS*⁸ databases. The unofficial data is obtained by using a bio-surveillance tool called *PADI-web* [2] which tracks online news articles on disease outbreaks. The extracted spatio-temporal unofficial data items has references to *ASF* disease and *porcine host* (either *wild boars* or *domestic pigs*). For both the data sources, we only extracted the events reported between the dates 2016-02-10 and 2017-11-10. The aspects tested in this case study are as follows:

- the usability of *EpidNews* in visualizing the official information about the two distinct hosts (*wild boars* and *domestic pigs*) of the disease *African swine fever*,
- detecting geographical ambiguities in the spread of disease using unofficial news items,
- visualizing the different data types (*diseases*, *hosts* and *symptoms*) contained in unofficial news sources together and
- comparison of geographical and temporal patterns in official vs. unofficial news sources.

5.1 Task 1: Visualizing & analyzing official news

For the first task, the expert selected the relevant disease (*ASF*) and varied the streamgraph slider to observe data in different time periods. She used the heatmap (Figures 6.a. and 6.b) to aggregate the outbreaks, which distinguished the high density areas (in red)

⁷<http://empres-i.fao.org/eipws3g/> (accessed on March 14, 2018)

⁸https://ec.europa.eu/food/animals/animal-diseases/not-system_en, (accessed on March 14, 2018)

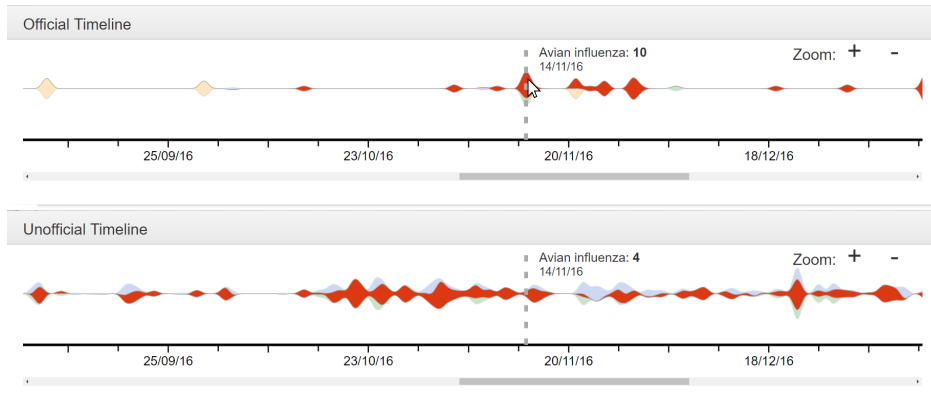


Figure 4: Representing and comparing temporal information on streamgraphs: number of news items about *avian influenza* in official and unofficial sources on the 14th of November 2016

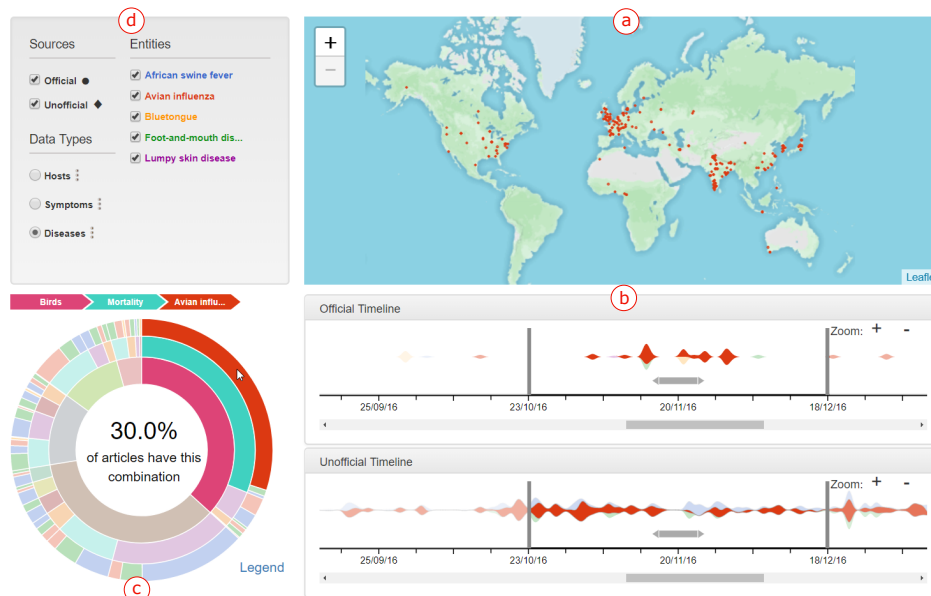


Figure 5: Synchronization between different views of *EpidNews*: (a) map, (b) streamgraphs and (c) sunburst

from the low density areas (in blue). This allowed the expert to understand the evolution of *ASF* outbreaks in Europe: how it spread from Eastern to Western Europe (in the second map, we notice less outbreaks in Ukraine and, also the first outbreaks in Czech Republic appear).

For comparing data of *ASF*'s hosts, the expert used the icon-map which presented *wild boars* in brown and *domestic pigs* in pink (Figure 6.c) making them easily distinguishable. While the *wild boar* cases are predominantly concentrated in the Baltic countries, *domestic pigs* outbreaks affect a larger and diverse area.

Observing locations of the official news items in Figure 6, a potential geographical abnormality can also be noticed: although

being constantly surrounded by *ASF* outbreaks, Belarus did not (officially) notify any *ASF* case.

The lasso tool helped the expert in focusing on particular locations independent of countries' frontiers. The dates corresponding to the selected news item locations are highlighted with dashed lines in the streamgraph. Selecting a cluster of outbreaks in western Russia, and then observing their corresponding dates that show up in the streamgraph (Figure 7), suggest that those *ASF* outbreaks were not only related in space but also in time: indicating a likely epidemiological link between them.

For some countries, dates for both "actual disease outbreak" and official "outbreak confirmation" are available. For example,

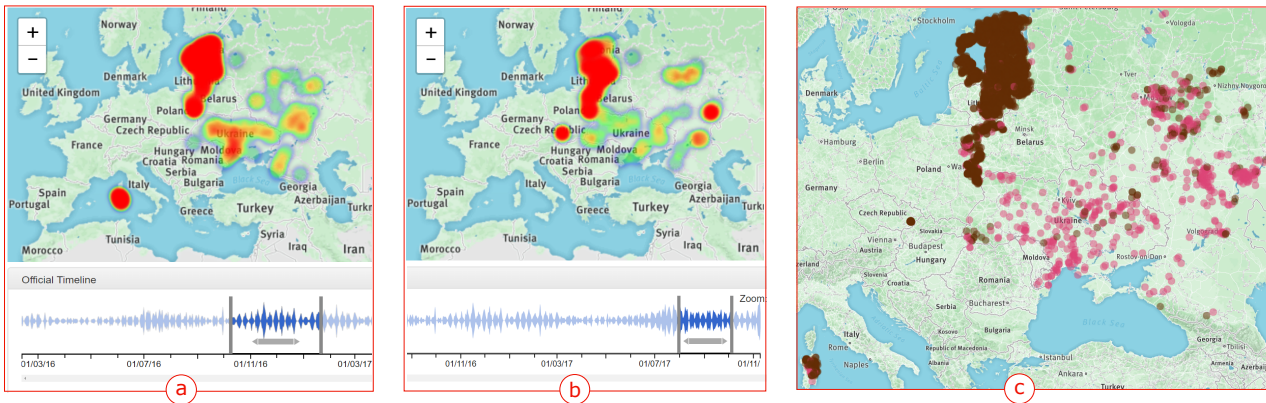


Figure 6: Distribution of African swine fever official outbreaks and their hosts using a heatmap and an icon-map. The heatmap represents the outbreaks (a) from 2016/10/10 to 2017/01/20 and (b) from 2017/08/01 to 2017/10/05. The icon-map (c) compares ASF hosts during the whole studied period with wild boars in brown, and domestic pigs in pink

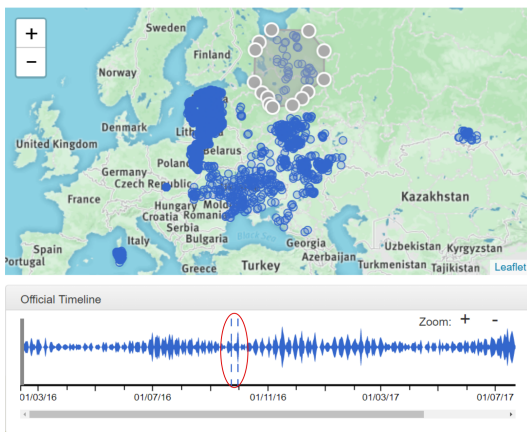


Figure 7: Streamgraph shows the highlighted dates for the selected locations in the icon-map using the lasso tool

comparing the data for Russia (Figure 8): with stream of disease outbreak in red and the stream of outbreak confirmation in blue, suggests that a cluster of cases which occurred in mid September 2016 were reported almost three weeks later by official sources.

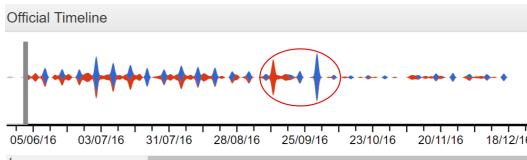


Figure 8: Actual outbreak date stream (red) & notification/reporting date stream (blue) for ASF related news in Russia

5.2 Task 2: Analyzing different data types

Some unofficial news reports can contain data which is not specific to the relevant disease: ASF (i.e. information about other diseases / hosts / symptoms). For instance, almost 76.5 percent of the unofficial reports had the combination of ASF and either domestic pigs or wild boars, which are the ASF specific hosts (Figure 9.a) and the rest 23.5% had mentions of other diseases and host combinations.

After evaluating the proportion of each combination of diseases, hosts and symptoms (Figure 9.b): it can be noticed that fever is the most common symptom associated with the ASF disease.

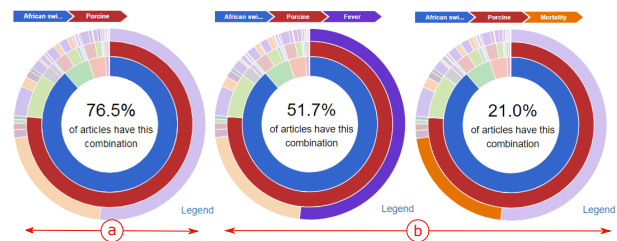


Figure 9: (a) Example of disease–host combination in unofficial news source. (b) Example of disease–host–symptom combinations in unofficial news source

5.3 Task 3: Further insights from the source of news articles

After observing the geographical distribution of unofficial data around Belarus the expert clicked on the glyphs on the map to know further details. It was found that the content of articles were relevant to ASF and Belarus. In fact, two news articles were about the pork ban imposed by Belarus due to the ASF outbreaks in the bordering countries and one was about the creation of a pig breeding center. Another one was a relevant news report which referred to outbreaks not reported by official sources (Figure 10).

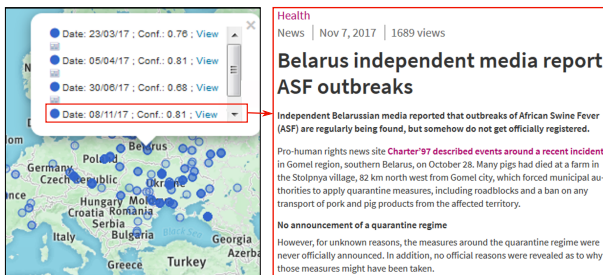


Figure 10: Source article for the news item on the map

5.4 Concluding the case study

EpidNews proved to be of immense help in easily analyzing the spatio-temporal news data. The expert found it useful in locating potential clusters of cases with an epidemiological link which can be validated with statistical methods. The visualization also helped detect bias in the dataset: like the potential absence of official notifications in some areas. *EpidNews* is definitely an efficient tool to analyze the epidemiological news along with the combination of three important indicators in animal epidemiology: *diseases*, *hosts*, and *symptoms*. It is also helpful in detecting geographical ambiguities and potential outbreaks which often go undetected by official sources. Therefore, this tool should be used in the daily monitoring and analysis of both official and unofficial news sources, thereby reducing the manual work of the epidemic intelligence team.

The expert in her evaluation mentioned that colors can sometimes be meaningful in the epidemiological context. For instance, *domestic pigs* are naturally associated with the color pink and *wild boars* with brown. However, currently the tool ignores these color associations and uses the most visibly distinctive colors. In fact, automatically assigning a specific color to a term is complex because the choice partly relies on the sociocultural context [21]. This limitation can be addressed by allowing the user to select or change the color for terms himself but also ensuring distinctive colors. The expert also suggested to cluster the glyphs of the icon-map to prevent cluttering issues when zoomed out beyond a certain level.

6 CONCLUSION AND FUTURE WORK

In this paper, we presented *EpidNews*, a new visual analytics tool for spatio-temporal news data which can be used for monitoring animal diseases. It combines several views, namely: map, streamgraphs and sunburst that help the users to manage news data from multiple sources and aggregate this information on different levels of abstraction. Thus, it allows the experts to easily analyze and track diseases outbreaks over different geographic regions and time intervals. Moreover, *EpidNews* was tested by an expert in epidemiology and the resulting case study is presented in the last section of the paper, which highlights the benefits of the tool.

In future, we firstly plan to address the two issues raised towards the end of Subsection 5.4. Secondly, our tool will be extended in order to cover other application domains as well, like environmental threats, etc. Eventually, we also aim to include other data representations and offer a dynamic view for the spread of a disease.

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