Illustrative Visualization of Hurricane Advisory Information*

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1 Introduction

The National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center's (NHC) Tropical Cyclone Advisories contain several heterogeneous data types that are difficult to represent graphically in a single image. However, the understanding of these statements is vital for human safety in areas that are regularly affected by these devastating storms. Thus, the motivation behind the current work is to develop new graphical representations of the advisory information using a single, coherent image, that conveys the past and present information about a particular storm of interest.

Inspired by artistic brush strokes, we have developed illustrative visualization techniques for representing the advisories. The NHC website represents wind swath information from past advisories related to each storm graphically as color-filled polygons. Other advisory information, such as storm position and intensity forecasts, are available in separate plots on the website. However, visualization research studies have shown that using separate plots can significantly hinder the ability to discover patterns in multi-dimensional analyses, especially when looking for combinations of conditions [2]. Furthermore, the use of color-filled polygons makes it difficult to encode additional information in the plot due to layer occlusion issues. Our new illustrative visualization techniques are designed to address these issues by mapping several of the advisory data attributes to the visual features of artistic brush strokes. By condensing the NHC advisory parameters into a single image, the current illustrative visualization method yields a promising approach to the dispensation of this vital information.

2 Related Work

Since the late 90s', illustrative visualization techniques have been employed to improve multi-dimensional displays. Researchers have drawn inspiration from oil paintings to develop visualization techniques that simulate the concept of underpainting and applied these techniques to the visualization of a second-order tensor field of a mouse spinal cord section in Laidlaw et al. [4] and 2D fluid velocity with a number of velocity-derived quantities in Kirby et al. [3]. Similarly, Healey et al. [2] studied oil paintings from Impressionist artists to develop new data-feature mappings for representing multi-dimensional weather data in a single image. Lum et al. [5] presented the kinetic visualization technique that uses particle motion along a surface to illustrate shape of structure of objects. These techniques have inspired the current work, which is described in greater detail in a separate publication within the ocean science community [7].

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3 NOAA NHC Advisory Data

The NHC advisories list the forecast and observation information for tropical or subtropical cyclones. Each advisory contains storm tidal information and a forecast of the storm positions, intensities, and wind fields for 12, 24, 36, 48, and 72 hours from the current time. Atlantic and eastern Pacific advisories are issued every 6 hours, or at any time due to significant storm changes. Based on the advisory specification, we developed a software module to retrieve the advisory statements for a particular storm or set of storms from the NHC advisory archive[1]. Although a great deal of information is contained in the advisories, the focus of the current work is on the wind quadrant radii, or wind swaths. An advisory may contain the wind swaths for tropical storm force winds (34 knots), storm force winds (50 knots), and hurricane force winds (64 knots).

4 Approach

After retrieving the advisories for a storm, the information is processed in chronological order. For each advisory, polygonal areas are created for the 34, 50, and 64 knot wind quadrant radii listings. Then, a rendering process uses these wind swath areas as the brush boundaries for drawing strokes along the trajectory of the storm. For each of the wind classes (34, 50, and 64 knots), the strokes are rendered along the trajectory of the storm from the previous to the current advisory. As the algorithm progresses, the swath shapes are morphed from the shape at the previous advisory to the shape at the current advisory. Using a standard incremental line drawing algorithm [6], the swath shape is rendered along the storm path by connecting the advisory locations. In addition to the swath shape rendering, the estimated center positions of the storm can be connected with a line to show the storm center track.

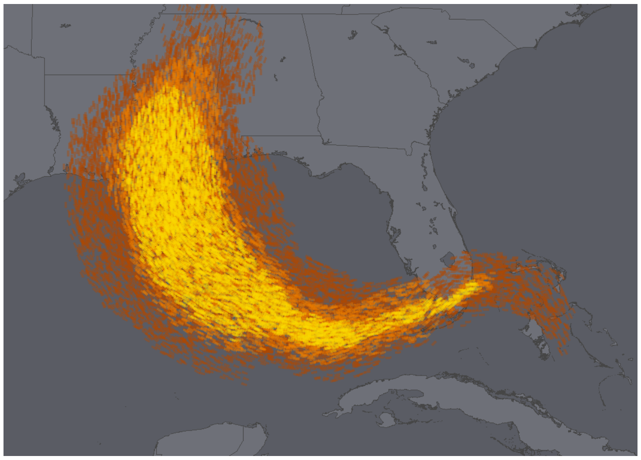
Separate images are maintained for each of the wind classes and the storm track line. When the visualization panel is rendered, the wind images are drawn over the background image in order of the wind speed beginning with the 34 knot area. The track image is drawn on top of the wind swath images. The resulting image highlights the most destructive areas for the viewer by drawing them on top of the other wind images. The interior of the swath shapes can be rendered using either a method that simulates small brush strokes or another that simulates long continuous strokes. Furthermore, a time-based fading effect is applied to the strokes as well as color labels for the wind swaths.

4.1 Small Brush Strokes

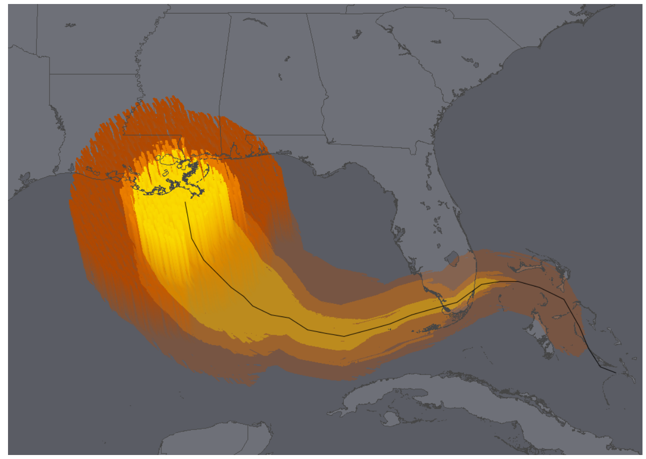
One method for rendering the wind swath area is to use small brush strokes, which is similar to the approach taken by Healey et al. [2] to visualize weather data. Instead of rendering filled polygons for the wind swath areas like the NHC graphical advisories, our approach uses the wind swath polygon as the boundary for rendering small, randomly placed strokes.

The small stroke rendering process begins by superimposing a regularly spaced grid over the wind swath polygon, which dictates where the brush strokes are drawn. A randomly generated sequence of the grid index positions is created and used to determine the order that each cell's brush stroke is drawn by using the stochastic sampling technique introduced by Cook [1]. This nonspatial jittering

[1]The NHC's Seasonal Tropical Cyclone Advisory Archive is available online at http://www.nhc.noaa.gov/pastall.shtml



(a) Small Brush Strokes



(b) Long Brush Strokes

Figure 1: Representation of 2005 Hurricane Katrina NOAA NHC storm advisory information using small and long brush stroke techniques. In (a), the entire track for Katrina is shown. In (b), the cumulative track is shown just prior to landfall.

technique reduces the noise level ensuring that strokes do not bunch up or leave large unsampled gaps. A spatial jittering is also applied before drawing the brush strokes. For each grid cell, the sample point is placed in the middle of the cell. Noise is then added to the x and y locations independently so that each sample occurs at some random location in the cell. Then, only the brush strokes whose centers (after spatial jittering) lie within the wind swath area are rendered. This process is applied for each increment of the storm track rendering algorithm mentioned in the previous section.

In Fig. 1(a), the small stroke method has been applied to the 2005 Hurricane Katina storm track. The color labeling and layered rendering for the wind swaths help the viewer to identify the area of the most destructive winds. The more times the wind swath is drawn over a particular area, the more dense the strokes appear with the small stroke method. This visual artifact indicates the amount of time that the storm has dwelt at certain geographic locations. The small stroke method allows us to encode additional information using the orientation of the strokes. The orientation of the strokes are determined according to the storm movement direction field in the advisory statement. Additional fields in the NHC advisories can be mapped to other visual properties.

4.2 Large Brush Strokes

Another method for rendering the wind swath area simulates long brush strokes. The resulting visualization gives the impression that a brush with large bristles or several separate small brushes have been dragged along the storm track. When the large brush stroke rendering is started, a texture is generated procedurally. In the current implementation, the texture is created by drawing circles in a rectangular texture where the radius of the circles are determined by computing the distance from the center of the texture. The circles are drawn on a regular grid using the spatial and nonspatial jittering techniques discussed previously in section 4.1.

The wind swath polygon for a particular advisory is then used to mask the outer areas of the texture by centering the wind swath polygon on the texture's center. The pixels that lie within the wind swath are transferred to the appropriate wind image for the current advisory position. As the algorithm draws the texture along the storm trajectory, an image of long strokes emerges in the visualization. In Fig. 1(b), the long brush stroke method has been applied to the Hurricane Katrina advisories.

4.3 Temporal Stroke Fading

In the NHC wind swath graphics there is a consistent color treatment of the filled polygons despite the fact that the areas most recently affected by the storm are generally more important to the viewer. We have developed another illustrative technique to yield a temporal fading in the long stroke method, which emphasizes the most recently affected locations.

This feature is implemented with a time counter that is stored for each pixel of the wind image. When a pixel is painted, the time counter is set to the maximum time value. Prior the rendering of each swath area, each pixel is visited. If the pixel's time counter is greater than 0, the pixel's alpha value is decreased proportional to the maximum time units and the time counter is decreased by 1 unit. The maximum and minimum alpha values are used to clamp the new color prior to updating the wind image pixel. The maximum and minimum alpha values ensure that the underlying image layers are partially visible and also that the track does not totally disappear in the visualization.

The temporal fading result is shown in Fig. 1(b) for Hurricane Katrina. This technique effectively utilizes the lower transparency to distinguish the geographic areas that have been most recently affected by the storm winds. The faded stroke visualization gives emphasis to the most recently affected areas while also providing the full context of the storm track.

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