Program 1 Extension: Time Animated, Illuminated Tuft Vector Field

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ABSTRACT:
Vector field flow visualization is a field which has seen many iterations and reiterations of similar ideas, especially in the realm of weather pattern visualization. Time animated heat maps have been used to show the motion of cloud cover over an area, tuft flow visualization aims to show vector flow in an area through more organic means than other visualizations such as arrow glyphs, and lighting systems have been designed in order to better convey direction and movement in field lines. The goal of this project is to combine aspects from all of these visualizations to show the change in wind flow over an area over time, using line-segment based tufts over a 2 dimensional space, animated by time sensitive data, and illuminated dynamically to better convey motion and direction in a dense visualization of weather data. This should help convey a large amount of wind data in a small space and time, while still being naturally readable to viewers.

1. INTRODUCTION

Scientific visualization of vector flow field data, specifically in the context of meteorological data for weather reports, has the ability to convey a large quantity of data across a vast physical space relevant to many people in a short amount of time. The best of such data visualizations can convey the largest amount of weather data in the smallest space. More specifically, conveying relevant, meaningful weather information in a way that can be quickly displayed and interpreted. Such displays can convey this data without introducing unnecessary complication, getting their messages across through natural and intuitive representation. This allows for a variety of information to be conveyed across a large physical space simply enough for anyone to pick out the specific data point relevant to them and their particular location. Therefor the display must be all of three things: dense, intuitive, and readable, in the sense that many data points can be conveyed quickly and distinctly.

Many different methods have been used to convey this data in this way previously. Section 2 goes over one such method closely related to this project in particular, but many others exist. It is common amongst such visualizations to use 2 dimensional glyphs transplanted on top of a map, as well as artificial heat map coloration to convey such data. While this visualization borrows from these ideas it depends on neither.

The core conceit of this visualization is to convey wind speed and direction across time in a way that requires less abstraction and rather a quasi-physics based representation which emulates the movement of blades of grass in the wind. We represent these as lines from a top-down perspective so as to keep the data easily understandable in the context of the physical space, and use simulated phong shading from an angle to best convey the motion and direction of these blades (hereby referred to as “tufts” in line with the paper by Wei Shen and Alex Pang referenced directly in section 2) without the need for artificial coloration. That said, heat map coloration is available in order to provide added contrast with the grayscale map used. Using these methods so based in real life physical phenomena, the visualization should be able to convey its high density of information at a glance, under the assumption that people will see the simulated wind physics and lighting, and automatically be able to intuit their meaning.

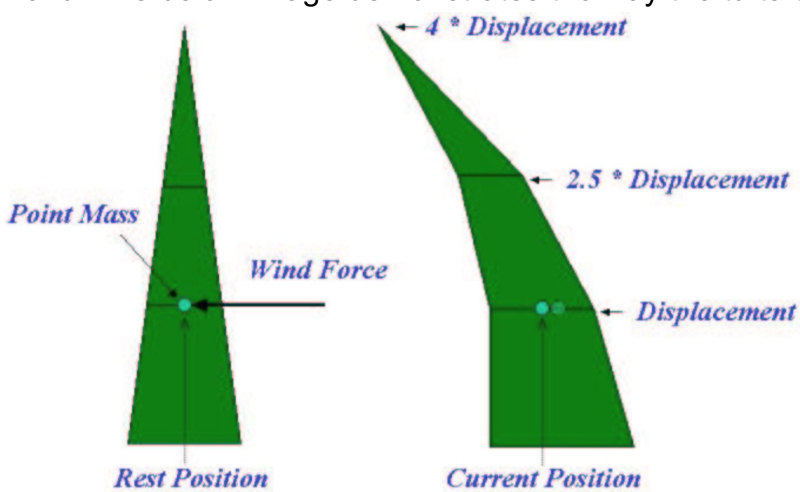
The rest of this paper continues as follows: section 2 gives an overview of related work and particularly those which directly inspired this visualization. Section 3 provides a rough overview of the code which sets up the display and interpolates the data. Section 4 goes over the code which sets the points, colors, and texture-mapping for the tufts, and section 5 provides a final wrap up on the results of the project.

2. RELATED WORK

This project draws heavily from two academic papers, Tuft Flow Visualization by Wei Shen and Alex Pang, and Fast Display of Illuminated Field Lines by Detlev Stalling, Malte Zöckler, and Hans-Christian Hege. It essentially operates by combining the best aspects of these two visualization methods, and combines them with animation over time and 2 dimensional space to maximize efficiency of conveyance. The following two subsections reflect the impact of these works.

2.1 Tuft Flow Visualization

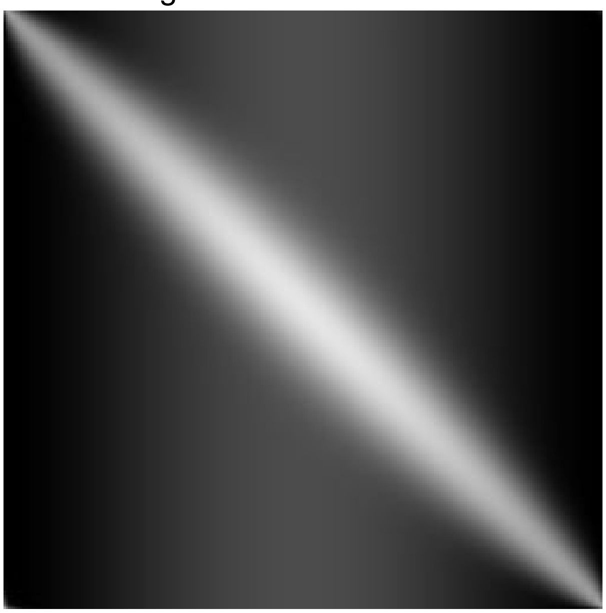
Tuft Flow Visualization seeks to re-examine the way vector flow field are represented by presenting this data as a series of grass-blade like tufts which respond to wind as physics objects. Namely, the idea is to take multi-segment triangles, make their base unmoveable, and have the segments further up displaced by the flow to an increasing extent further up the stalk. This method is very intuitive and easily readable because of how it reflects the way wind flow effects something commonly seen by people in the real world. The below image demonstrates the way the tufts bend in response to wind force:



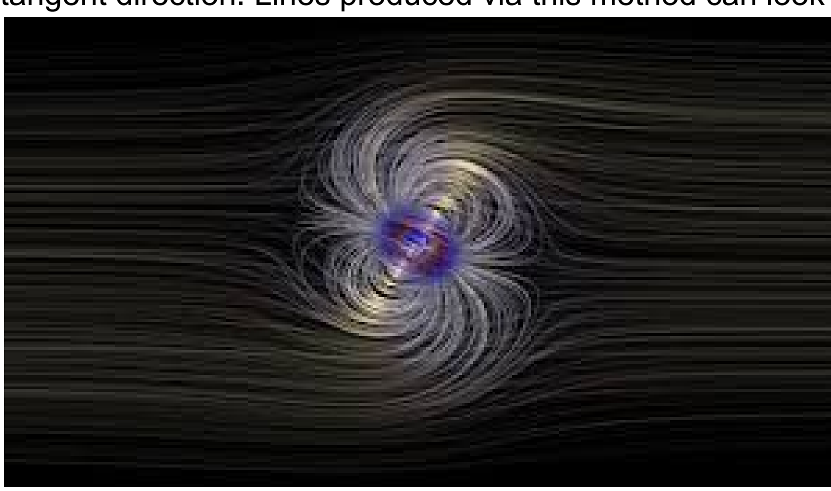
In this paper, displacement (as it is referred to in the above image) is calculated as a result of wind force, and the push and pull of spring force and a damping force per each segment.

2.2 Fast Display of Illuminated Field Lines

The paper Fast Display of Illuminated Field Lines proposes a way to color lines so as to simulate phong shading (shading taking into account ambient lighting as well as diffuse and specular lighting from a light source) via texture mapping on lines so as to more quickly allow them to be rendered in a realistic and readable way. Doing so allows the lines to have more easily read direction and motion, as well as making them more easily distinguishable from one another in a group. The texture map posed in the paper takes the following form:



Where the x axis represents the dot product of the light direction and line tangent direction, and the y axis represents the dot product of the view direction and the line tangent direction. Lines produced via this method can look generally like this:

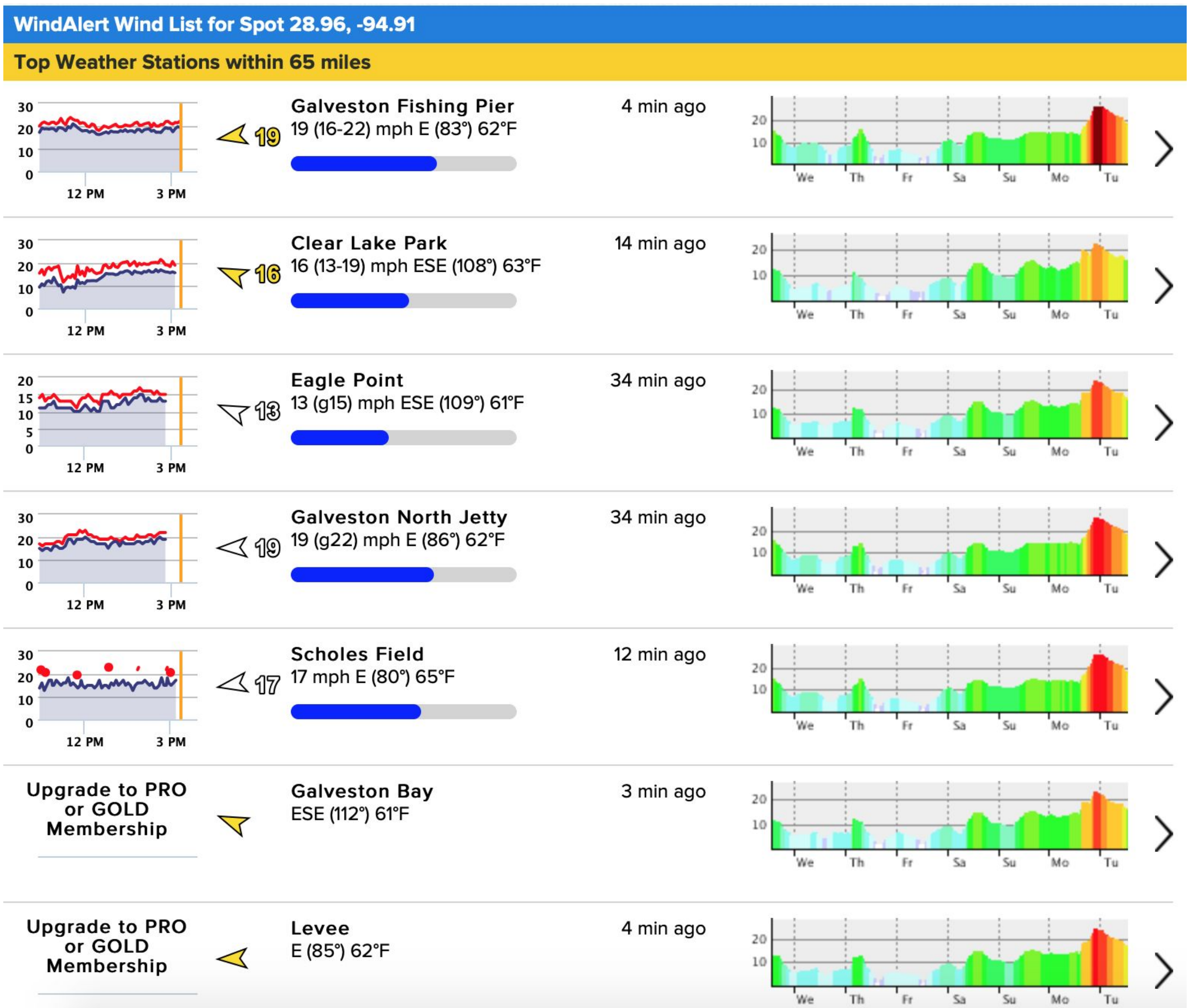


3. TECHNICAL DETAIL

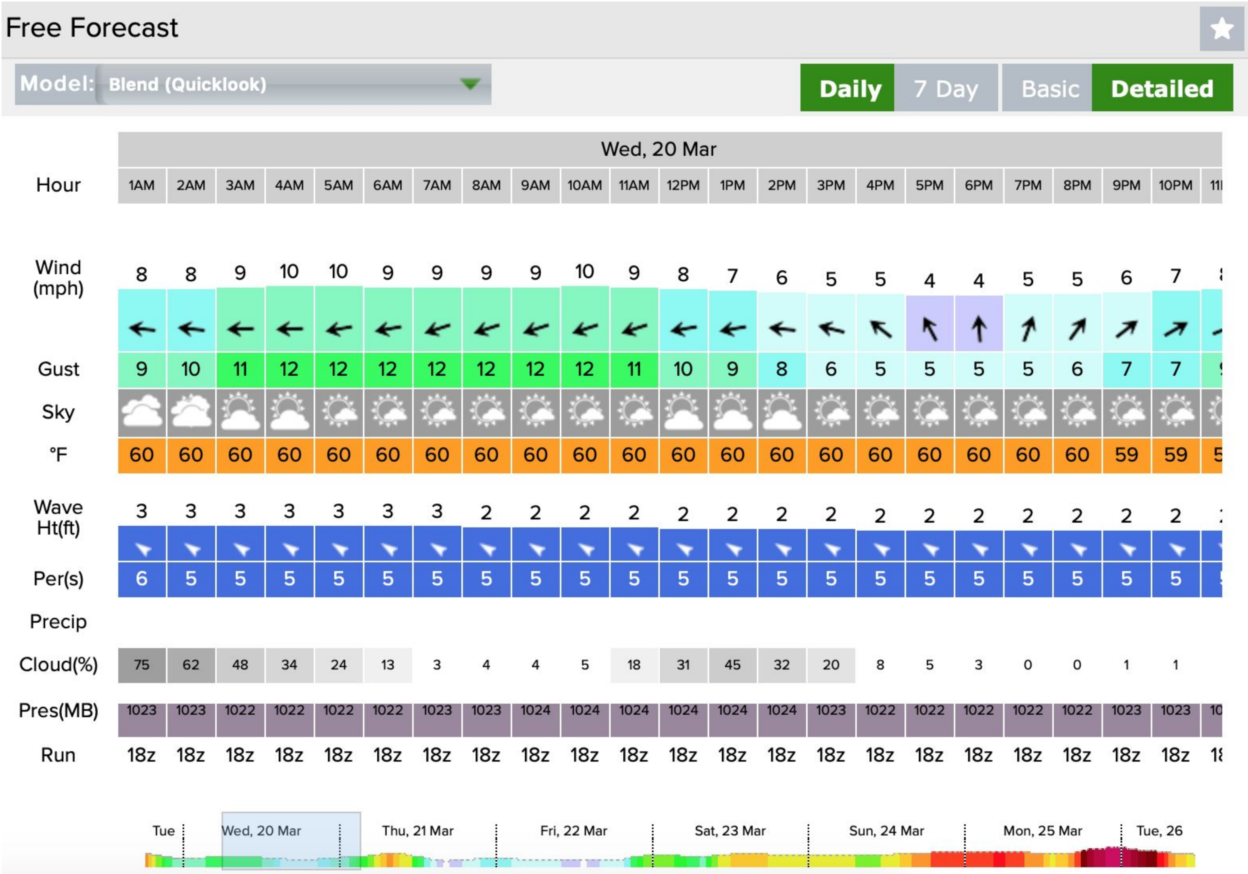
3.1 Data and Interpolation

The data this project seeks to represent is forcasted weather data for the date March first 2019. Specifically, wind speed and velocity over the Houston and Galveston gulf coastal region, covering a span of longitude from 94 degrees west to 96 degrees west, and latitude from 28 degrees north to 30 degrees north.

Data for this project was collected from https://windalert.com/windlist/28.961/-94.908. Specifically from a selection of 48 meteorological stations in the area of question. Below is an example of how Windalert presents its data collection stations:



Each of these location options leads to a forecast display like the one below:



	Wed, 20 Mar																					
Hour	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM
Wind (mph)	8	8	9	10	10	9	9	9	9	10	9	8	7	6	5	5	4	4	5	5	6	7
Gust	9	10	11	12	12	12	12	12	12	12	11	10	9	8	6	5	5	5	5	6	7	7
Sky																						
°F	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	59	59
Wave Ht(ft)	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Per(s)	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Precip																						
Cloud(%)	75	62	48	34	24	13	3	4	4	5	18	31	45	32	20	8	5	3	0	0	1	1
Pres(MB)	1023	1023	1022	1022	1022	1022	1023	1023	1024	1024	1024	1024	1024	1024	1023	1022	1022	1022	1022	1022	1023	1023
Run	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z	18z

The data per hour in at these stations were compiled into a series of objects designed to store the position of and data collected at each station. Specifically, data for speed and angle of wind flow at each station are collected into arrays, each with 24 entries for the data at each hour, and each frame of the final animation.

These objects are then altered to convert their positions from longitude and latitude coordinates to world coordinates on the 600 by 600 html canvas object.

After this, we construct a 150 by 150 grid of these objects using shepherd's interpolation on the collected data. We do not interpolate over time, as the smallest unit of time used here is 1 hour per frame, and our collected data is per hour already. This interpolation takes some time due to the fact that we need to perform 150x150 interpolations from 48 base data points, 24 times for each hour for both speed and angle. However, this interpolation is only done once at the beginning, and never again, allowing for a better frame rate on the actual animation.

After this grid has been created, the animation loop can begin.

3.2 Animation

The animation is run by an interval event triggering a draw function regularly for a framerate of 6 frames per second. Generally the animation looks best at this or 8 frames, as though this is generally slow, it gives enough time to properly take in the information on display. It should not take users multiple loops to find and process the information being presented for their specific corner of the overall map.

Rendering is done on a per tuft basis, generating one tuft for every 2x2 grid points. Doing so at every grid point leads to clutter, whereas displaying tufts at an even lower resolution loses some of the effect of the animation as one coherent field of tufts. The goal here is to make the display such that users can both pick out individual details, as well as take in wind flow over the area as a whole if they so choose. Each tuft goes through a process of transformation and then lighting / coloration each frame.

3.2.1 Tuft Transformation

Each tuft is created as a series of 3 line segments, or 4 distinct points. The first is centered at 0,0,0, and each point going upwards from that is displaced in the x direction by a factor of displacement, times an increasing coefficient going higher up on the line. Displacement is calculated by combining the wind speed at the grid point at that time with a value for air density obtained from http://www.ajackson.org/wview_files/ to get a wind force value. This wind force value is then used to calculate a spring force which attempts to root the tuft in place. A spring constant of 2 is used, to allow the tufts to bend just enough to be visibly bent when viewed from above, but not so much as to stop reflecting light properly, which is touched on in the next subsection. By combining these forces, we can find the tuft's displacement value for when the wind and spring forces reach an equilibrium state (i.e. net force equals zero). No damping force is used, as it would only add noise to our time-sensitive data animation.

After this, tufts are rotated based on the angle of the wind at their location, so as to point the right way, and then tufts are translated to the position whose data they represent.

3.2.2 Tuft Illumination

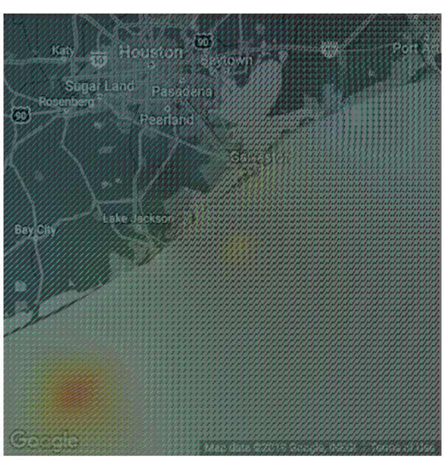
The illumination calculations are made with the viewer looking straight down at the canvas, and with directional light in the direction 0.5, 0.5, -1, or down and at a 45 degree angle on the x and y components, to allow dynamic reflection on the sides of the lines which best reflect their motion in this display. From here the method described in the paper referenced in section 2.2 is used, with a slightly modified texture map from the one used in that paper. The only meaningful difference is that the ambient lighting has been increased, so as to better show off the colors of the tufts when that setting is on, even despite facing in a direction which does not reflect much of our directional light. Below is the texture map used.

On this image, the x coordinate represents the dot product of the light vector and the normalized tangent vector of the line segment, whereas the y coordinate represents the dot product of the view direction vector and the tangent vector. Doing so allows us to more quickly shade the many lines which make up our display. Additionally, color can be applied to the brightness of the texture mapping based on a standard heat map if desired.

4. RESULTS

The animation is best viewed when rendered in real time, as the time component is vital to our display, however, below are images representing the display the above methods generates. First is what one tuft essentially comes out to.

When put in context of one another the tufts gain more meaning, however.



Options for grayscale and pause are also present, should users which to filter data more precisely.

5. CONCLUSION

For time sensitive, location specific data visualization meant to cater to many different people's needs as quickly as possible before they continue going about their day, tools such as tuft flow visualization and field line illumination can be used in tandem with good design principles to create visualizations which display large quantity of data across time and space readably at a glance. This visualization is one such example, allowing for a dense visualization which represents data in an intuitive way which maximizes the effect of context, both in the physical space of the virtually unobstructed map (given Gestalt psychology), and in reference to the overall changes in windflow represented by the densely populated and shaded tuft field.

6. REFERENCES

Tuft flow visualization concept:

Tuft Flow Visualization by Wei Shen and Alex Pang

Line illumination:

Fast Display of Illuminated Field Lines
by Detlev Stalling, Malte Zöckler, and Hans-Christian Hege

Wind Data:

https://windalert.com/windlist/28.961/-94.908

Air density approximation:

http://www.ajackson.org/wview_files/

Brief gestalt psychology reference:

https://www.britannica.com/science/Gestalt-psychology