REPORT

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3D visualization of weather forecasts and topography

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Abstract

Advances in computing power and graphics have increased the use of graphics in weather forecasting. This includes 3D animation sequences and geographical information systems. The paper addresses the main problems and presents preliminary results of the visualization of atmospheric models in conjunction with the underlying topography. The goal is among others to make a sort of 3D satellite pictures that present the weather described by the gridpoints in an atmospheric model, i.e., the weather of tomorrow.

Keywords: Visualization, weather forecasting, terrain models, geographical information systems, meteorological models.

1 Introduction

In most countries, weather forecasts conduct the basis for planning outdoor activities, especially offshore work. In the StormCast project we currently construct a workbench for meteorologists at regional weather institutes, including distributed artificial intelligence application for wind forecasting, monitoring of weather data, visualization of weather forecasts (from numerical models) and different multimedia data (incl. video, audio and satellite pictures).

Computer forecasts are made by dividing the area of the forecast into a series of horizontal locations, called gridpoints. Above the gridpoints, the atmosphere is divided into a series of vertical levels. The data are received from different sources in order to derive the pressure, wind, temperature, and humidity at each gridpoint at a particular time. The derived values are then used as starting points of the computer calculation. This calculation yields the future pressure, wind, temperature, and humidity at each gridpoint within a limited period, called the time-step. Given gridpoints 50 km apart and 18 vertical levels, for the northern part of Europe, there exists 121*97*18 gridpoints (= 211.266).

In the visualization-subproject we focus on different techniques for visualization of the atmospheric model. The goal is among others to produce satellite pictures of tomorrow, i.e. to make 3D satellite pictures that present the weather described by the gridpoints in the atmospheric models. In the visualization-project, we offer change of viewpoint, zooming, one or more lights, shading and transparent volumes. The model covers the northern part of Europe. An important part of the visualization is the underlying topography.The topography need to be closely connected to the atmospheric model in order to offer the needed functionality. Using digital terrain models in conjunction with atmospheric models is the first step towards a 3D geographical information system (GIS) where we will be able to model the development of hurricanes etc. Based on these models we will be able to take our precautions in order to prevent major or minor disasters.

The paper will, focusing on the integration of topography and meteorological data, describe the system architecture, discuss the problems and chosen solutions and present further works.

2 Visualization of topography and meteorological data

At present, the Norwegian Institute of Meteorology (DNMI) operate at a very low resolution with gridpoints 50 km apart. In this respect there is only need for 2D map projections as a background to the weather. However in the near future DNMI will be able to produce weather forecasts with gridpoints 5 km apart. Given this it will be of great interest to visualize formation of clouds, direction and speed of the wind etc. together with the underlying topography. The first version of the application will only be able to predict the weather, but further on we will animate the development of the various weather parameters in order to give a real-time viewing of the weather. The future GIS should also be expanded to be flexible in the sense that it will be possible to predict what effects the weather will have. One possible scenario will be to show the amount of rain over a specific period. It shall then be possible to show what effects this will have on the rivers. Will this rainfall cause a flood or not? If it does, what effects will this again lead to with respect to the agriculture? One can easily think of other scenarios where the weather can cause damage and the various scenarios will be application dependent.

2.1 Topography

One common way of presenting topography is by digital terrain modelling (DTM) (Weibel and Heller, 1991). DTM is a 2.5D rather than a 3D model, such that for every x, y-coordinate, there exists only one z-coordinate. In this respect we find it suitable to use a DTM to present the topography. It should be possible to specify camera position, light position and view position in order to get a realistic view of the scenery with shades and appropriate colors. This is best done with some kind of shading technique, like for example Bui-Tuong (1975) shading.

It should be possible to zoom in and out of the topography, which requires several sets of topography at various scales.

2.2 Scalar fields

The scalar fields should have varying density to reflect, for instance varying wind speed. If we look at wind speed, the light winds should be transparent and heavy winds should have a lesser degree of transparency.

It should be possible to move the viewpoint inside the scalar field, i.e., to have a camera position inside it. Hence it should also be possible to specify the camera position, light position and view position in the same way as for the topography.

3 System architecture

The StormCast project operates on a set of autonomous workstations connected by an Ethernet. These are general purpose computers with only minor graphical hardware-support. In this respect it is most necessary to distribute the heavy computations involved in rendering. However, the rendering operation can be viewed in two phases. One in which the desired extract is decided, and another in which high quality and high resolution pictures are generated.

This paper focuses on the task of integrating the volume data and topography, i.e., to make a tool that can be used to order a high quality picture. The intention is both to make a kind of draft tool and to make a tool for generating low-resolutions weather forecast illustrations. Figure 1 presents a model for this.

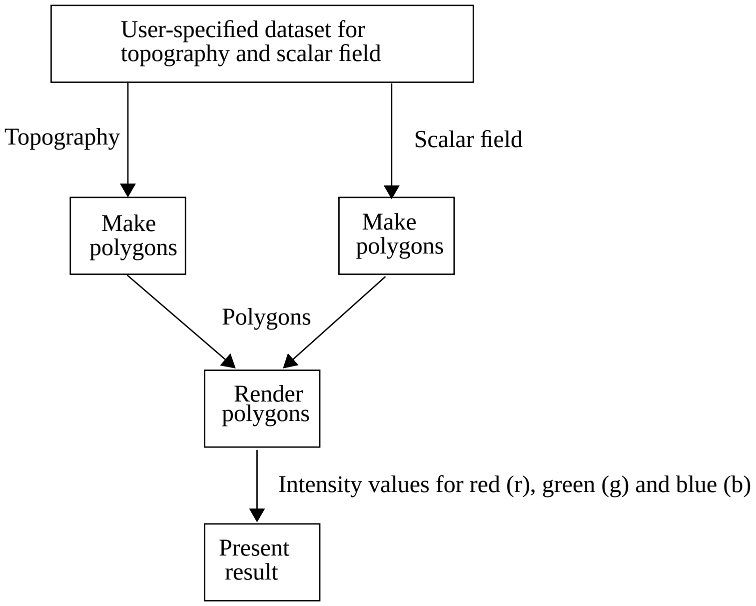

FIGURE 1. A model for the visualization of topography and scalar fields.

To represent the topography we have chosen to use a quadtree (Samet, 1990). This allows us to easily represent several sets of topography covering the same area with different resolution. The quadtree is also very suitable for spatial searching. The topography is originally represented as 2 dimensional binary matrixes in which the dimensions seldom has lengths as powers of two. Because of this we have introduced a pseudo matrix for the building of the tree. In order to speed up the process of rendering we give the user the opportunity to reduce the data set by setting a difference value. If the values inside a quad do not differ with more than the specified “diff” value, then we remove all its vertex points except the four vertex points that makes up the quad. Figure 2 illustrates the concept of pseudo matrix and reduction of vertex points.

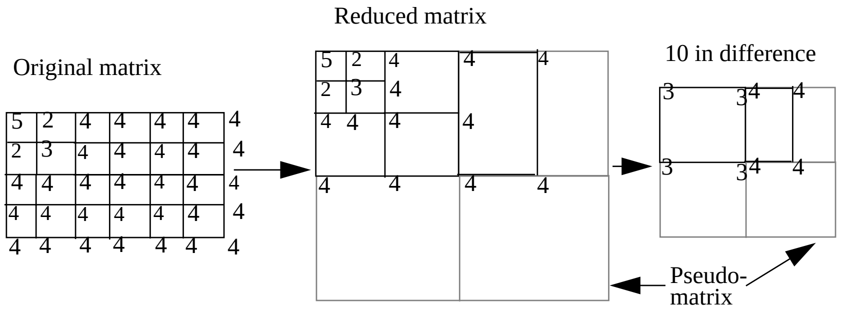

FIGURE 2. Concept of pseudo matrix and specification of difference for further reduction.

The scalar fields are also originally represented as binary matrixes, but with a dimension of three. In order to convert the volume data to a polygonal representation, we use the marching cubes algorithm by Loerensen and Cline (1987). This algorithm computes triangles of a specified value and a gradient for each triangle. In this version we use the rendering library Sipp 3.0 (Yngvesson and Wallin, 1992) to shade the resulting scene, so we do not have to compute the gradients.

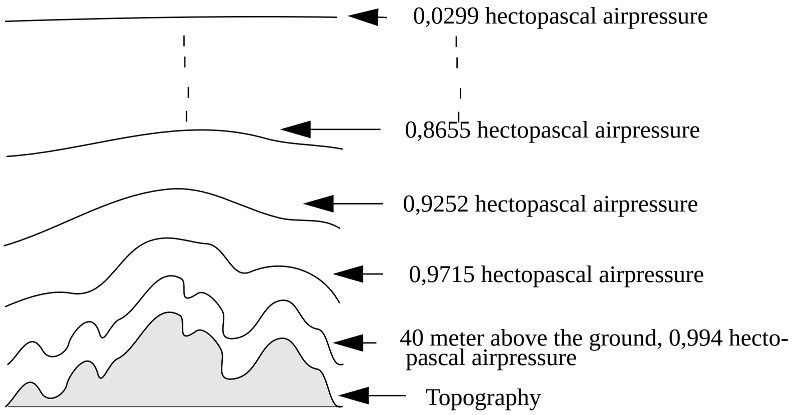

FIGURE 3. Model of the topography and levels of air-pressure.

One problem with the marching cubes algorithm is that it expects a regular 3D matrix. The 3D matrix we uses is indeed a regular one, but the model is only regular in the x, y dimensions and not in the z dimension. This can be illustrated as in figure 3.

Figure 3 shows that the lowest layer in the model follows the topography at an altitude of roughly 40 meters. The next layers go from following the topography to gradually following certain pressures of air. To deal with this we interpolate the height value of the vertices of every triangle that “marching cubes” generates, according to a 3D matrix which specifies the height of every gridpoint in the model.

4 Results

This integration of topography and meteorological data gives us the opportunity to both present satellite pictures, and a perspective view of tomorrows weather. The tool is able to present the total situation, as well as extracted information of important weather parameters, e.g. areas with wind speed at specific limits. Figure 4 shows a perspective view with a camera position in the Atlantic ocean looking towards Europe with Britain in the center and the Alps to the right. The two red volumes represent wind at a speed of 44 meter per second.

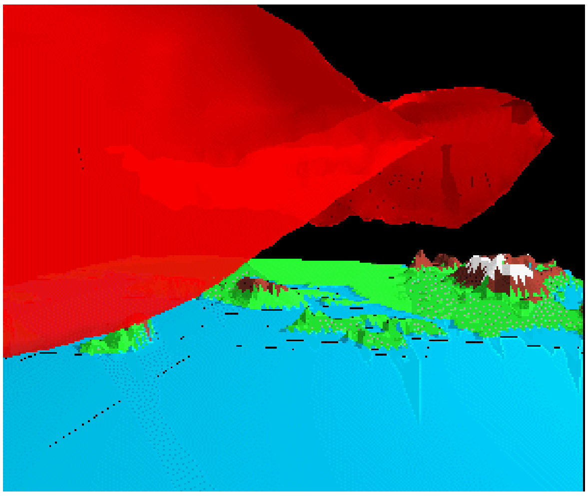

FIGURE 4. A view from the Atlantic ocean towards Europe with 44 m/s wind volume. (Great Britain is in the middle, the Alps to the right.)

The number of polygons to make up this scene is 12200 for the topography and 14100 for the wind. The time to generate the polygons is 49 seconds and 4 seconds respectively and the rendering time for the whole scene is 16.5 seconds. This is done on a standard HP 9000/735 machine with 48 Mb of RAM. The time used in the calculation of the topography is due to the fact that during the polygon generation we calculate a color for every polygon. These colors should have been precalculated in order to save time.

The connection of a 3D matrix (atmospheric model) with a 2,5 D terrain model is done straight forward by converting the scalar data to the same polygonal format as the topography. The major disadvantage with this scheme is that the ability to visualize intervals of values the marching cubes algorithm will produce a huge amount of polygons which is very memory intensive. Other approaches to rendering polygonal and volume data also exist, e.g., (Levoy, 1990).

5 Discussions and open problems

As indicated earlier in this paper the time to visualize a scene by doing it as a sequential process is not satisfactory if interactivity is required. To explore an interactive potential it is necessary to parallelize both the process of generating the polygons and the rendering process. In order to let the user decide which algorithms is the best for what he is going to visualize, we suggest that the application should support the use of several different algorithms (Avila et.al., 1992).

We think of this as a first step towards a 3D GIS and in this respect we should include a more detailed topographic description, such as borderlines, cities, roads, stony grounds, fertile soil, rivers, waves in the ocean etc. It should then be possible to visually present what effects the weather will have on these specific items.

6 Concluding remarks

In this paper we have presented an application for visualizing meteorological volume data in conjunction with its underlying topography. This is to be seen as a first step towards a 3D GIS which is supposed to both visualize weather prognoses and the effects the future weather might cause. This kind of tool will also be of great help at meteorological institutes and in their effort to make accurate prognoses.

Especially the visualization of specific parameters has been appreciated, e.g., the notification of wind speed and temperature areas of special interest are of great value for air traffic as well as sea going vessels.

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