VISUAL PROCESSING OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION IN THE BASQUE COUNTRY: TWO CASE STUDIES

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Abstract. The Basque Meteorology Agency is conducting an initiative to improve the collection, management and analysis of weather information from a large array of sensing devices. This paper presents works carried out in this context proposing the application of 3D geographical visualization and image processing for the monitoring of meteorological phenomena. The tools described allow users to analyze visually the state of the atmosphere and its interaction with the topography, and process live outdoor images to automatically infer weather conditions. This kind of systems can be applied in the surveillance of other environmental events and enable better decision making for several purposes, including important issues related with environmental security.

Keywords: visual analytics, GIS, geographic information, computer graphics, weather, meteorology, environmental security.

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Book Title Information

1. Introduction

Geographic information processing together with computer graphics visualization and analysis has a considerable potential in environmental monitoring and decision making. The Basque Meteorology and Climatology Agency along with VICOMTech Research is conducting a strategic project that aims at establishing tools to centralize and enable analysis of the large amounts of data collected from weather sensors spread around the Basque Country. These sensors are heterogeneous devices such as those in 96 automated weather stations (temperature, pressure, humidity, wind, solar radiation, etc.), a Doppler radar, a wind profiler and several oceanic probes.

This paper presents work carried out in the context of this initiative that brings computer graphics-based tools to assist in analyzing the global situation. Properly using the data from sensors requires calibration procedures and filtering of noise to ensure reliability.

The first part of the work involves the creation of an integrated 3D geographic information system for visually analyzing weather data, mainly weather radar scans, together with other georeferenced information. The work starts with an analysis of output data from the weather radar located on Mount Kapildui and the task of improving the quality of the readings.

The second part proposes video cameras as additional weather sensors. Computer vision techniques can process images coming from cameras in the automated stations and provide information on the state of the local atmosphere. A coordinated operation of all stations with such a system installed could give a global depiction of the state of the sky along the territory and its evolution, potentially allowing the forecast of special environmental situations.

1.1. GEOGRAPHIC VISUALIZATION AND IMAGE ANALYSIS

The Autonomous Community of The Basque Country is a territory in northern Spain bordering with southern France. It spans an area of 7234 km^2 and is crossed by a few mountain ranges. Established 1990, the Basque Meteorology Agency, *Euskalmet*, has deployed a large network of automated weather stations, including a long-range radar, and provides past, present and forecast meteorological information.

The physical data collected by sensors in the network needs to be stored and properly managed and retrieved to provide useful information (e.g. for decision making). This process involves the use of traditional tools as well as innovative computer visualization and image processing as key technologies. Visual analysis tools help users understand the state and evolution of the environment by providing integrated graphical representations and visual metaphors.

In the case of weather and other environmental information we consider geographic (i.e. topographic) data especially relevant. These phenomena occur in specific locations and are influenced by the topography. We thus want to present incoming sensor data coupled with a detailed 3D representation of the territory in order to give it a context and allow a visual analysis of the interaction between ground and atmosphere.

The above mentioned system transforms numerical sensor readings into visual representations to enable humans to interpret them. This initiative also proposes a system working in a very different way: taking live images of the environment, as a human observer would, and automatically process and interpret them to infer the state of the environment.

Both approaches (producing visual metaphors for humans to interpret and letting computers interpret visual information) are different aspects of the application of computer graphics processing in environment related information analysis. Current focus is in meteorology, but a similar approach can be applied to other environmental monitoring such as forest fires, pollution or floods, all with implications in environmental security.

2. Weather radar data processing and visualization

The Basque Weather service operates a dual Doppler Weather Radar, located on top of Mount Kapildui, 1000 meters high and 100 km away from the coast. It is a Meteor 1500C model from Selex-Gematronik. The radar computes the reflectivity, radial velocity and spectral width fields every 10 minutes through two volumetric and two elevation scans.

Radar scans are typically represented as 2D images in the form of either PPI (plan position indicator) or CAPPI (constant altitude PPI) products. Here we want to display the complete radar volumes, not only individual slices from it, correctly aligned and scaled over digital terrain model of the territory. The result is a form of a geographic information system (Peuquet 2004).

2.1. VOLUMETRIC DATA ANALYSIS

The volumetric data sets acquired by the radar are composed of 14 scans at increasing elevations (from –1º to 35º). Given the topography of the Basque Country, the lower scans are affected by the surrounding mountains and other topographical elements, adding almost constant noise to the data, which should be ignored. This constant noise is known as ground clutter.

Ground clutter is noticeable in the lowest elevations, since the radar beam frequently hits the topographical elements. On the other hand, the lowest levels give more useful information to meteorologists, so a compromise has to be found. Normally, the lowest elevation free of clutter is used as the main information source. In Mount Kapildui clean scans can be obtained at elevations greater than 1º. It would be better to have lower scans (at –0.5º, 0º and 0.5º), but this part contains noticeable ground clutter.

Since ground clutter is in theory constant in time its effects in the lowest scans can be reduced by subtracting a fixed mask to the retrieved data. Basically, this clutter mask consists of the reflectivity acquired in a clear day. Under those conditions, all perceived reflectivity should be caused by surrounding topography.

We have observed that ground reflectivity is not exactly constant but has slight random variations from one scan to another. This is probably due to slightly changing atmospheric conditions and small movements of the radar support structure.

2.2. CLUTTER MASK CREATION AND SUBTRACTION

Given the variability of radar echoes caused by topography a single scan of a clear sky is not enough to create a reliable clutter filter. In order to avoid this problem, a clutter mask was created through a combination of a small set of radar scans taken at different times with a clear sky.

The resulting mask effectively removes clutter from the scans used to produce it, by definition, but may not filter correctly all ground echoes in other scans due to those random variations. In order to increase its effectiveness, the mask is processed by a *dilate* filter. While this increases the risk of producing a filter which is too aggressive our preliminary tests seem to give acceptable results.

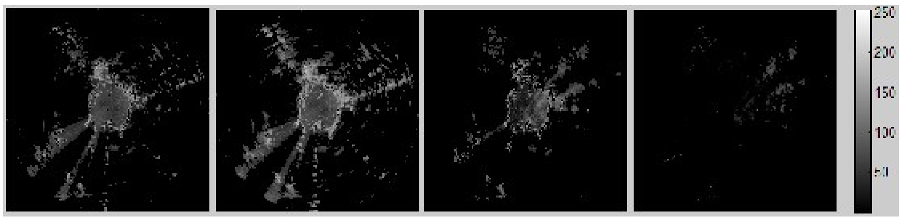


Figure 1: A low level scan subtraction. From left to right: a) original clutter mask, b) dilated clutter mask, c) a random volumetric scan and d) the subtraction of the scan and the clutter mask, removing the ground clutter.

Figure 1 shows a combination of several slices, its dilated form and an example of application (subtraction) from a new incoming reflectivity slice.

2.3. 3D VISUALIZATION ON GEOGRAPHIC MODEL

Our model of the Basque Country is based on a detailed digital elevation model (Jenson 1988) and a set of properly adjusted high resolution orthophotographs, provided by the Basque Government. In order to allow rendering at interactive rates the original elevation data in GeoTIFF format and the textures were processed to produce a set of hierarchically arranged tiles of varying resolution. The resulting data set, almost 1 gigabyte in size, enables progressive level of detail by retrieving the required terrain tiles on demand.

Volume scan files include metadata specifying the geographical location of the radar (longitude, latitude and elevation) and the sample separation. This information is used to position and scale the reflectivity field on the map. The map uses UTM coordinates and since the Basque Country is located nearly in the middle of zone 30T, very small scale distortion is expected.

The union of radar and topographic data clearly highlights the presence of ground clutter around the highest mountain ranges (see figure 2). The application currently also allows applying a precalculated clutter mask to remove such noise and produce cleaner precipitation representations.

Two visualization styles have been tried. In the simplest one, reflectivity is mapped to the opacity and greyscale intensity of all slices. In the second one, a standard reflectivity colour map is used, and values lower than 10 dBZ are completely transparent, which seems to be more intuitive to meteorologists.

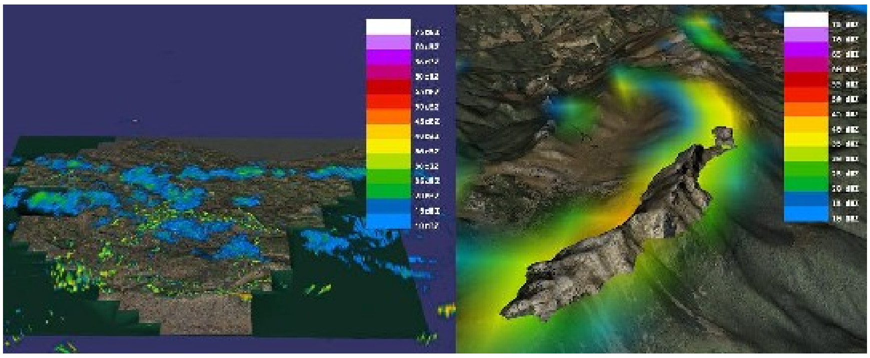


Figure 2: Unfiltered Kapildui radar volumetric information visualization using a reflectivity color map. In the left image, the rain areas can be seen in blue as well as ground clutter. In the right image, a close up of the ground clutter is shown, matching the mountain causing it.

3. Automatic analysis of sky images

The main goal of the Skeye project consists of the automated visual analysis of the images acquired by cameras located on ground stations. The Skeye architecture allows the integration of any analysis module and in this context we will focus on cloudiness estimation and fog detection that can provide information about the visibility condition in this area. Figure 3 shows the different modules developed to compose the Skeye system.

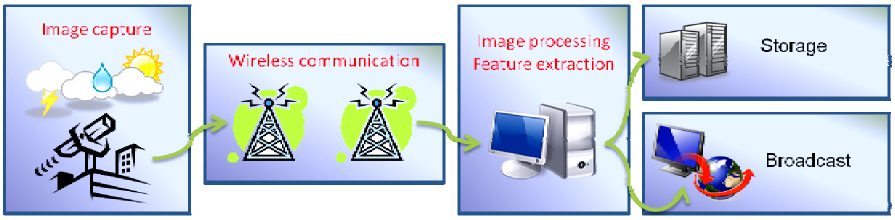


Figure 3: Skeye System Architecture

3.1. IMAGE CAPTURE

This module works at the terrestrial weather station. It takes pictures of the sky covering all elevation angles from –10º to 90º and 360º in azimuth.

Pictures can be taken in the visual electromagnetic spectrum or in infrared band. Infrared cameras have some advantages since they can work at night and the images provided contain thermal information, but on the other hand, texture-based analysis algorithms get less accurate data as input.

The amount of necessary images to cover the whole sky is inversely proportional to the field of view of the camera (Kelby, 2006). The quality and properties of the images depend on the camera parameter's settings which will be adjusted according to the environmental light conditions. The proper calibration of all these parameters will have a strong influence in the system's final precision and recall.

Data transmission is not a trivial aspect in our case. Terrestrial automated weather stations are usually placed at remote locations and the scalability of the system requires wireless solutions to keep the costs in a reasonable level. Therefore, this project has been coordinated with a WIMAX network deployment that will ensure the delivery of the information from all these remote stations. Mobile telephony networks such as GSM, GPRS, UMTS or HSDPA are also being considered depending on signal coverage.

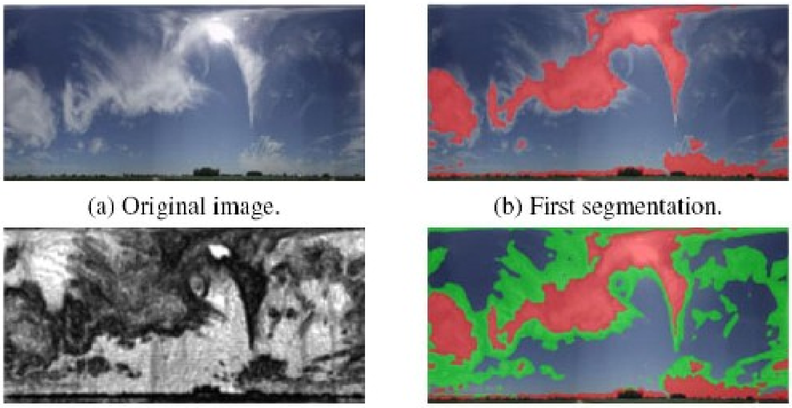
3.2. IMAGE PROCESSING

This module centralizes all the information coming from the different terrestrial weather stations. It creates a 2D panoramic view of the whole sky dome keeping areas' relations using geometric transformations and Gall-Peters projection mode (Peters, 1983). This function allows representing the local weather conditions in a unique image and centralizing the visual information from the geographically separated places for the meteorologist.

Furthermore, it analyzes the images and extracts features using digital image processing techniques in order to segment the image and carry out the cloudiness calculation and fog detection which are processed by independent software modules.

For cloudiness, the image is segmented and labeled in 4 classes: *Earth*, *sun*, *sky* and *cloud*. Color and texture (entropy) features are used in this process (see figure 4).

The fog detector is based on the topographic outline analysis. The local terrain shape is analyzed and assumed to be fixed. Shape variations provide hints to detect fog which disturbs the terrain visual observation.



(a) Original image. (b) First segmentation. (c) Entropy values. (d) Second segmentation.

Figure 4: Cloud Segmentation Process

3.3. DATA STORAGE AND DELIVERY

The processed information is stored in common servers where different meteorological stations upload their data. This information can be accessed from anywhere and used to combine many data sources. It provides the way to find correlations among geographically separated weather phenomena and their effects or to track features in very wide areas.

4. Environmental monitoring

The potential of these two presented use cases operated by Euskalmet go much further than simple local weather analysis applications. The idea behind is a global approach to data analysis where different kinds of data (visual information, radar readings, digital terrain models, etc.) coming from different places can be combined in order to get a better understanding the state and evolution of environmental phenomena. These include weather alerts involving potential floods or fast temperature changes, chemical leaks to the atmosphere, forest fire and smoke, etc.

Current existing network infrastructures where communications costs are dramatically reduced by wireless technology deployments and the availability of a wide range of sensors and cameras provide a huge amount of data that after adequate preprocessing phases can be analyzed for different purposes. Data mining techniques can also help discover unknown correlations among geographically separated features and effects improving the knowledge of researchers and professionals.

Moreover, the network of stations can be considered as single entity able to carry out surveying activities of the areas covered by the network nodes. Some interpolation techniques could even find out effects produced in non monitored areas located among nodes.

5. Conclusions

A novel weather analysis system has been presented in this paper. In combination with classical weather instrumentation (thermometers, barometers, anemometers, etc.) the two use cases offer methods to improve forecast, general knowledge and environmental surveillance.

The Doppler weather radar visualization system with the explained clutter filtering techniques and more integrated sensors will provide the basis for a new data source to help prevent natural disasters like floods and big storms, and allows defining behavioral patterns.

The Skeye project defines a centralized image analysis framework where different cameras can be connected. All the visual information is processed by pre-calibrated analysis modules and cloudiness degree and fog presence can be automatically estimated.

6. Acknowledgements

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