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Tracking Hurricane Paths*

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Abstract

The South East coastal region experiences hurricane threat for almost six months in every year. To improve the accuracy of hurricane forecasts, meteorologists would need the storm paths of both the present and the past. A hurricane path can be established if we could identify the correct position of the storm at different times right from its birth to the end.

We propose a method based on both spatial and temporal image correlations to locate the position of a storm from satellite images. During the hurricane season, the satellite images of the Atlantic ocean near the equator are examined for the hurricane presence. This is accomplished in two steps. In the first step, only segments with more than a particular value of cloud cover are selected for analysis. Next, we apply image-processing algorithms to test the presence of a hurricane eye in the segment. If the eye is found, the coordinate of the eye is recorded along with the time stamp of the segment. If the eye is not found, we examine adjacent segments for the existence of hurricane eye.

It is probable that more than one hurricane eye could be found from different segments of the same period. Hence, the above process is repeated till the entire potential area for hurricane birth is exhausted. The subsequent/previous position of each hurricane eye will be searched in the appropriate adjacent segments of the next/previous period to mark the hurricane path.

The temporal coherence and spatial coherence of the images are taken into account by our scheme in determining the segments and the associated periods required for analysis.

1. Introduction

A significant improvement in the prediction of natural calamities, have a profound social and economical impact on people. Among other natural events, hurricanes take longer time to shape up and move compared to earthquakes, tornadoes, etc. However, as hurricanes cover vast areas, a large number of people and pets would need to be relocated.

A correct prediction can save lives and helps to minimize property damages. In contrast, an incorrect prediction would cost a lot of effort and financial resources for the government and individuals. This demands an increased accuracy of hurricane predictions. Tools and methodologies used by meteorologists, play a vital role in the accuracy of weather predictions.

Remote sensing satellite images and aerial photography [2] provide immense amount of data for timely forecasting. Efficient processing [5] of these vast amounts of data is crucial to extract essential features for hurricane predictions.

In this paper, we attempt to provide an automated method to track hurricanes from their births through all stages. The next section presents the analysis of satellite images for hurricanes. Section 3 describes the method for determining hurricane paths. The last section outlines conclusive remarks and future work.

2. Analysis of satellite images

Weather satellite images are obtained in the form of area files (Geostationary Operational Environmental Satellite images). As these images

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cover wide areas of earth, they require large amount of memory for processing. For this reason, we decompose satellite images into segments of small size. The segment where there is a high probability of hurricane development is examined first. This will speed up the hurricane search process.

The structure of the process of tracking hurricane paths is shown in Figure 1. The process begins by selecting an image segment that is highly probable for hurricane birth. The segment is evaluated to assess the cloud coverage. This is carried out with image processing techniques (conversion to gray scale image, reduction in brightness and increase in contrast with no gamma correction or techniques similar to those outlined in [1]) as in Figure 2 and Figure 3. Subsequently the cloud coverage area and the distribution of clouds are computed.

If the cloud cover parameters of the segment are greater than a threshold value (that is dependent on the type of images and the segment size), the segment may be associated with a hurricane. If not, the segment is discarded and another segment is selected for hurricane presence test.

If a segment passes the cloud cover analysis, next we examine if a hurricane eye is present in the segment. We perform this by applying image smoothening techniques such as water color method to remove extraneous noise from the image (see Figure 4). Then we check if the segment has a closed region of black pixels present inside the segment. This is ensured with the application of a flood filled algorithm from all boundary pixels of the rectangular segment (replacing black pixels by another color) and then we search for the presence of black pixels inside the segment.

There could be multiple black regions that may be potential hurricane eyes (four regions in Figure 4). To identify if any of them qualify as the hurricane eye, the following tests are performed. First, the bounding box of each cloud region as well as each black region is computed. The height and width of these boxes are evaluated for the presence of the cloud size indicative of a hurricane and the black region indicative of its eye. If multiple black regions within a cloud region pass the above test, we calculate the relative position of these regions with respect to the cloud region and select the black region that is closest to the center of the cloud, as the hurricane eye. The coordinates of the hurricane eye along with the time stamp of the segment are stored in a database.

If the segment contains a potential cloud region at the border of the segment with no hurricane eye, the eye could be present in a spatially adjacent image segment. In such cases, the new segment is defined to enclose all parts of the cloud region from the adjoining segments. Then the hurricane eye presence test is repeated for the new segment.

3. Calculation of trajectories

To determine the subsequent temporally coherent position of the already identified hurricane eye, adjacent segments of spatial and temporal coherence [4] are examined. The temporal and geographical features of the eye are stored in a database along with other hurricane-related parameters that are monitored by other sources. The trajectory of the hurricane path [3] is interpolated between temporally successive eye positions.

The process of finding the eye and the trajectory calculation is repeated temporally and spatially until the eye cannot be identified at which the hurricane has lost its strength. This completes the calculation of the hurricane trajectory. The trajectories of past hurricane paths could be plotted along with the current trajectory for the comparison of hurricane paths.

4. Conclusion

In this paper, we have presented a scheme to analyze satellite images to automatically locate hurricanes and their eyes by exploiting both spatial coherence and temporal coherence. Storage of images of all past hurricanes demands enormous amount of storage space. Demand based access and analysis of these image data sets are computationally expensive. Hence our method would analyze the data once and store only the trajectory and the hurricane associated parameters.

The method described here will not provide an accurate prediction, but enables forecasters to account visually presented information of past hurricanes that are spatially and temporally relevant to a present hurricane. With sophisticated hardware support, real-time analysis of hurricane position could be computed to furnish timely information for emergency rescuers.

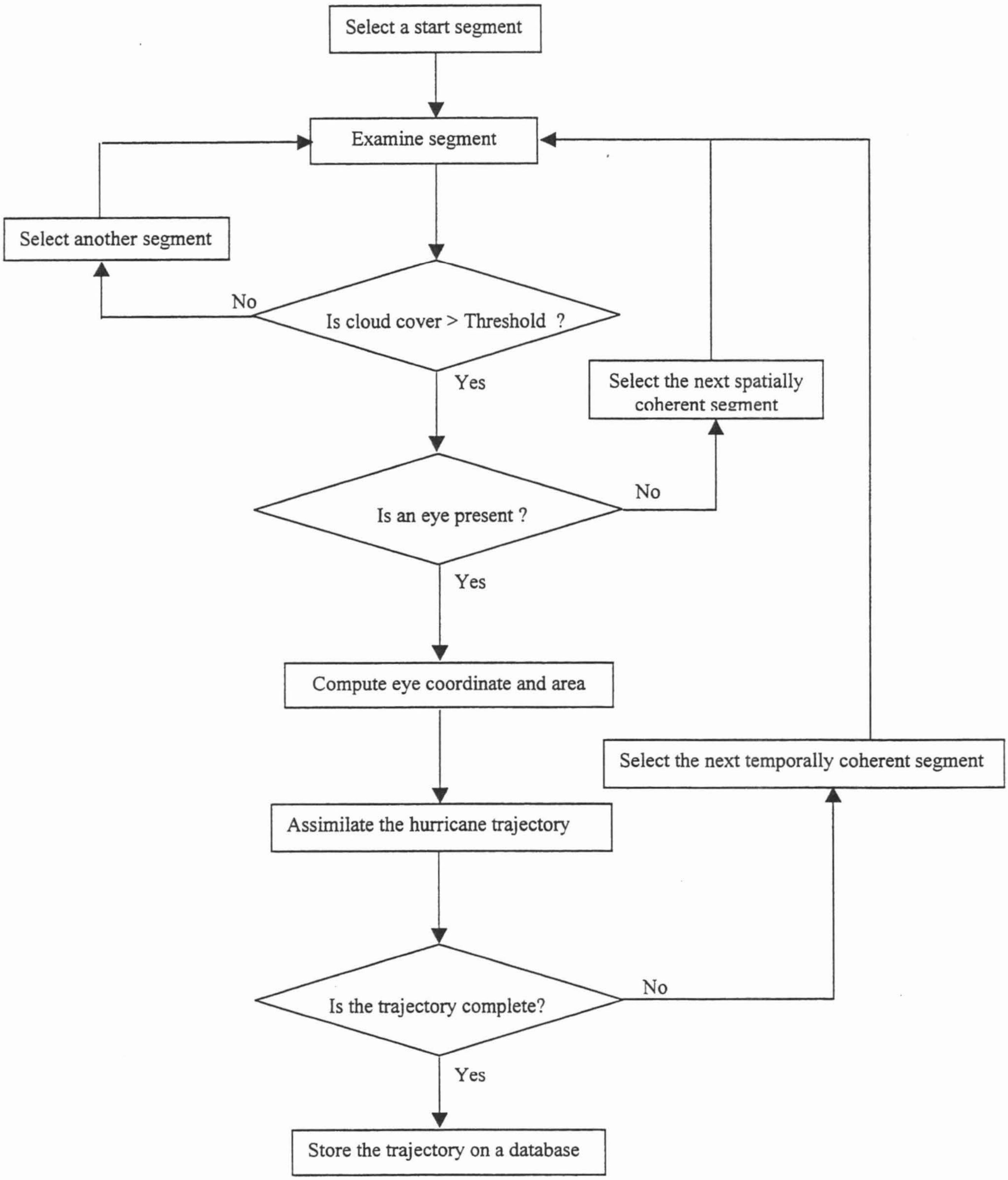

Figure 1. Proposed structure for tracking hurricane paths

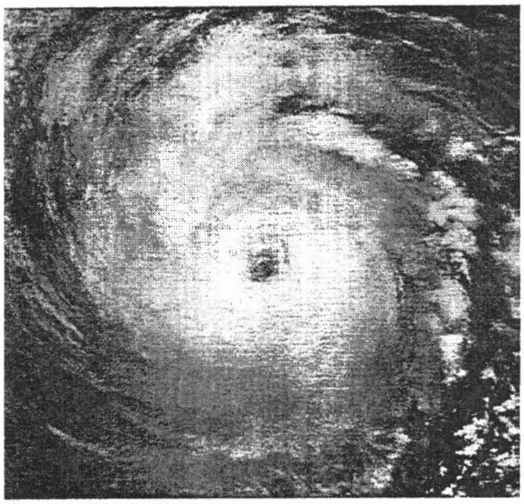

Figure 2. Gray scale image of a segment with a hurricane eye

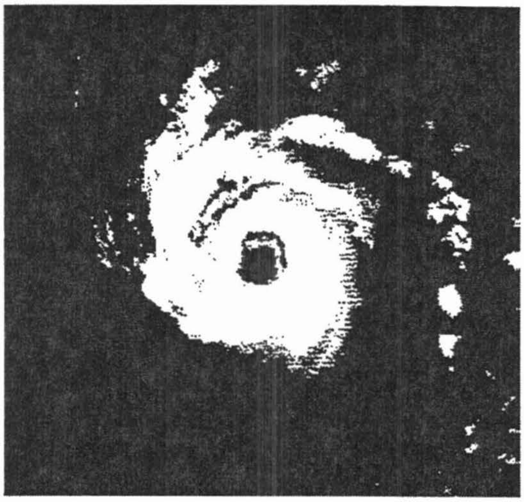

Figure 3. Image after brightness and contrast manipulations

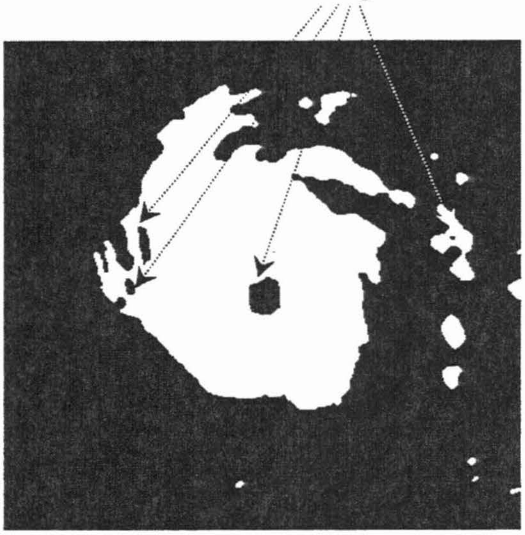

Figure 4. Image after smoothening noise

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