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Annual Technical Progress Report (End Year 1)

Aurora Phenomenon Localization, Classification, and Temporal Evolution Tracking

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1 Introduction

This report is a summary of the progress for the first 12 months of effort on the AISR award NNG-06-GE60G. The project officially began on March 15, 2006.

1.1 Problem Background

Our work aims to produce an improved on-line search tool to the large archive of aurora images produced by the NASA Polar mission's UVI sensor and the IMAGE mission's FUV sensor. There are approximately 9 million images in these collections, and it is challenging for researchers to find all images of interest for their investigations.

Previously, Co-I Germany developed the On-line Search Tool (OST), an interface to the database of UVI images. The tool allows retrieval of images based on time of collection and some simple auroral features. While OST was a great advance, it is limited in that it can retrieve based only on a few simple features. It is also limited by various complications in the images, including high levels of noise, low contrast, and stars in some images. Finally, presence of day glow in many images can confuse the methods used by the tool's image miner. There is no existing tool that allows retrieval of FUV images based on simple auroral features.

The project aims to improve the robustness of the existing OST to image complications and to extend the OST capabilities to allow FUV retrieval. In particular, one aim is to develop more robust methods to locate the auroral oval in the imagery, primarily by exploiting the known shape of the auroral oval. Given the auroral oval, characteristics of the aurora in each image can be determined, allowing retrieval of imagery based on aurora characteristics. A second aim is to support retrieval of images based on temporal features, for example, retrieval of images during substorm onset.

2 Brief Progress Summary (Results to Date)

In this section, the progress on the project is briefly summarized. Many low-level details have been omitted; our aim is to provide a fairly high-level summary of progress.

During the first year, we have had three major accomplishments: (1) the shape-based auroral oval detection mechanism has been extended to FUV imagery, (2) a suite of methods to detect theta auroras,

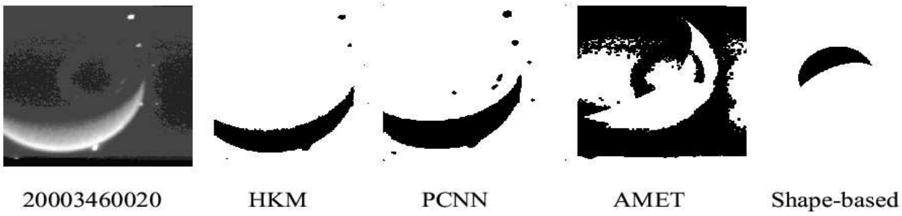


Figure 1: Comparison of Auroral Oval Detection Methods for FUV

auroras with trans-polar activity, standard auroras, and “thick” auroras in UVI imagery was completed, and (3) a method for improving the accuracy in auroral oval identification and shape estimation in UVI imagery was developed. Progress was also made toward a substorm detection mechanism. We do not discuss the latter item in detail here since it is a work in progress.

2.1 Extending Oval Detection Method to FUV

One of the major accomplishments during the year was the development of an approach for automatically locating the complete auroral arc in FUV imagery. The approach is shape-based and is an extension of the work that we completed under prior AISRP funding. (That prior work was reported in [3], and the technical basis for that work was reported in [4].) The new approach is described in work that will be presented at the Machine Vision Applications conference next week [2]. To our knowledge, our work is the first reported effort for auroral oval detection in FUV.

The shape-based method that we developed for application to UVI imagery will not work correctly if applied to FUV imagery, as shown in Figure 1 for one FUV image. The other existing UVI auroral oval detection methods also fail, as shown in the same figure. The reason for the failure of all the methods is the very large, bright region of dayglow in most FUV images, including the one shown in Figure 1. (The dayglow is the large crescent near the bottom of the image.) Most of the methods mistook the dayglow for the auroral oval.

The method we have developed in the project exploits the fact that auroral oval shape is elliptic in FUV and UVI images, as we have discussed in reports on previous AISR projects. The method’s basic processing scheme is shown in Figure 2. The major change that was made to the shape-based processing to allow application to FUV was to first remove the magnetic local times (MLTs) in the image where dayglow could occur. Then, the outer oval was found using the remaining parts of the image. Another change was to find the inner oval boundary by restoring to the image all regions inside the outer oval. Such processing allowed the dayglow effects to be overcome in a way that allowed reasonably accurate detection of the auroral oval’s extents.

2.2 Detecting Thetas and Other Special Cases in UVI

We also completed an effort, begun in a prior AISRP project, that allows detection of theta auroras, auroras with trans-polar activity, standard aurora, and auroras that are “wide” in UVI imagery. That work was presented in October 2006 [1].

An outline of the processing steps for detecting thetas is illustrated in Figure 3 for a UVI image

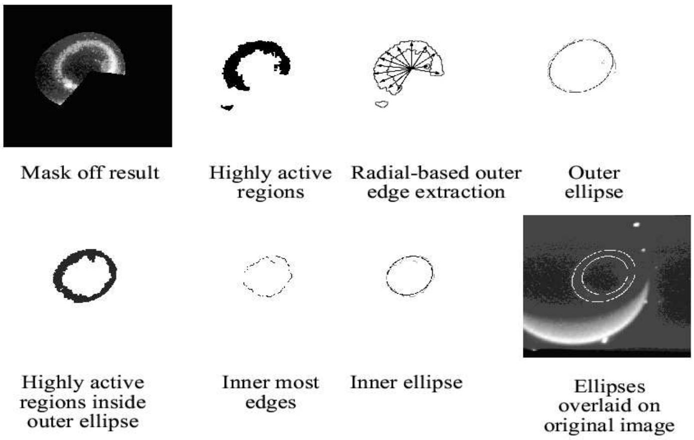


Figure 2: Shape-Based Method for Auroral Oval Detection in FUV Images

from 1999. The main idea is to first find and remove the parts of the image associated with the auroral oval itself, leaving only trans-polar structures. Then, the degree of linearity of the trans-polar structures is determined. Highly linear structures are taken to be theta auroras. (If the structures are not highly linear, the case is taken to be an aurora with trans-polar activity.) The whole processing is driven by the shape-based method's identification of the auroral oval; processing for theta detection is limited to the region inside the auroral oval.

Standard auroras were taken as those with no appreciable trans-polar activity. Wide auroras were taken as those whose widest distance between the inner and outer auroral oval boundaries was more than 1500 km.

We have conducted a benchmark experiment to estimate the performance of the methods for classifying auroras as theta, standard, and wide aurora types. The precision of the methods averaged about 85% and the recall averaged about 80%. The full experimental results were reported in the October 2006 paper [1].

2.3 Improving Oval Identification Accuracy

Although our shape-based method for extracting the auroral oval in UVI imagery has been demonstrated to be superior to the existing methods, it nevertheless does not produce a perfect result. Recently, we have developed a new mechanism that can improve its performance. This mechanism, in fact, has broader applicability in that it can improve ellipse detection in other cases that utilize the same core methodology that we use. That core methodology is the randomized Hough Transform (RHT). The RHT, while producing results in a reasonable amount of time and with good accuracy, can yield sub-par results if the object in the image has a somewhat noisy boundary. Specifically, RHT-based methods can estimate that the shape of an elliptical object in an image can be slightly bigger or smaller than the actual shape. The position or orientation of the object can also be estimated to be slightly

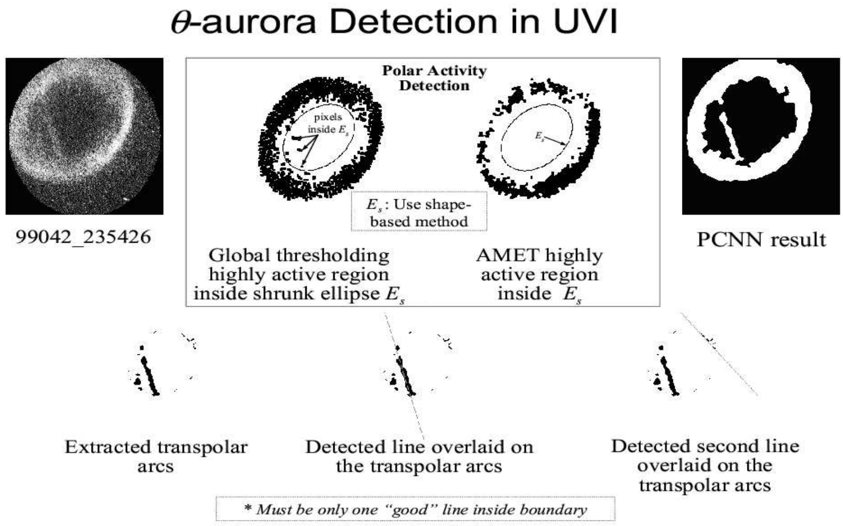


Figure 3: Theta Detection

displaced from its actual position or orientation.

One way to improve the robustness of RHT-based methods is to consider the distinctiveness of the recovered parameters. We have developed a new mechanism for measuring elliptic parameter distinctiveness which is applicable to RHT-based ellipse recovery. Our work was motivated by recent work in the literature [5]. The work has been accepted for presentation this summer [6].

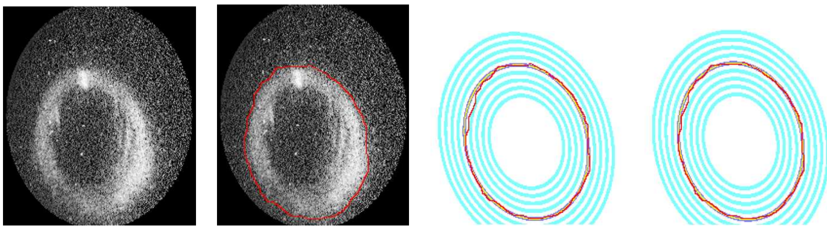
The crux of the mechanism is to examine a family of curves that are similar to the one that the initial processing identified. The new measure that we developed to accomplish this end provides better results than does the other recent mechanism [6], at least for application to auroral imagery.

Figure 4 illustrates the improvement from the new mechanism. The figure shows one UVI image in part (a) and a manual identification of the auroral boundary in part (b). In part (c), the manually traced boundary is shown in red and the fitted boundary from use of our basic RHT-based processing is overlaid in green. In part (d), the manually traced boundary is shown in red and the fitted boundary from use of the RHT-based processing coupled with our new curve distinctiveness mechanism is shown in green. In parts (c) and (d), the family of curves that were checked are also shown (in blue). The result shown in the figure illustrates that the curve distinctiveness measure can allow modest improvements in auroral oval localization.

We have found the method we developed to be robust, even in the presence of various forms of image noise. In the future, we may be able to use the shape information determined from the localization process as features to support image mining based on shape.

3 Plans for Next Year

The key issues to be addressed in the next year are incorporation of the methods into the OST and the creation of a version of OST that supports FUV data. Work on substorm detection and tracking will



(a) (b) (c) (d)

Figure 4: (a) Original image (b) Manually traced outer boundary (c) Old Method vs. Manually traced boundary (d) New Method vs. Manually traced boundary

also take place.

One journal paper is also currently under review. A second submission is planned for the near future.

4 Contributions to Education

We also would like to note some educational outcomes arising out of the report. One Ph.D. student supported during Year One of the project, Chunguang "Ken" Cao, should defend his dissertation shortly. Mr. Cao has been first author of many papers [1, 2, 3, 4] resulting from his work on the project. A second Ph.D. student supported for a few months of the project has also produced one publication as a result [6].

5 Conclusion

Three major initiatives have seen good progress in the first year of the project, as identified in the report. Our project is close to its target for the year one goals. We hope for an equally-productive second year.

References

[1] C. Cao, T. S. Newman, and G. A. Germany, "Shape-Based Mechanisms for Content-Based Retrieval of Aurora Images," *Proc., Wavelet Applications in Industry Proc. IV*, SPIE, vol. 6383, pp. 63830T-1 to 63830T-12, Boston, 2006.

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[3] C. Cao, T. S. Newman, and G. A. Germany, "Shape-based aurora oval segmentation from UVI images," *Eos Tran. AGU*, 86(52), Abstract SM51B-1285, 2005.

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