Classifying Aurora Borealis: From Human Eyes to Machine Vision

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Classifying Aurora Borealis: from human eyes to machine vision

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Project Description

Aurora borealis offers an entrancing, dramatic, magical display that fascinate all who see it. Since it is caused by charged particles originating from space that have been accelerated along magnetic field lines toward Earth, auroras act as a screen onto which the dynamics of space is projected. Auroras have various spatial shapes, and it has been long realized that different shapes are characteristics of footprints of different processes in space. Numerous efforts have been made to classify auroras and to investigate when, where, and how each type of auroras occurs.

Today’s auroral research utilizes ground-based cameras fitted with a fish-eye lens. For example, in year 2007 NASA deployed more than 20 all-sky cameras over north America to take images of auroras every a few seconds. These cameras have been operating every night in the winter season, producing millions of images every year. When studying properties of some specific auroras scientists often manually select events. However, with the explosive growth of auroral images, the event identification process becomes hampered by the laborious task of sifting through large data.

Given the prosper of artificial intelligence nowadays, it becomes obvious that intelligent algorithms capable of automatic pattern recognition can reduce manual labor and overcome the difficulties caused by subjectivity of the classification. It is therefore the goal of this project to apply machine learning to auroral science where the machine is trained to automatically classify auroral images depending on the observed features. The algorithm to be used is supervised learning; where the model is trained with labeled training data. Once the model is optimized, it can make predictions about unseen or future data. The specific objective of this RCEU program is to create a training dataset of labeled auroral images that are applicable to model training.

Student Duties, Contributions, and Outcomes

Duties. The student will utilize data from all-sky imagers that are part of an ongoing NASA mission named Time History of Events and Macroscale Interactions during Substorms (THEMIS). The student will discern auroral features from the image data (as the cameras at times also record clouds, stars, and moonlight) and distinguish several representative types of auroras, including auroral arcs (one or multiple bands of aurora that stretch across the field-of-view), auroral surges (auroral vortices that often propagate zonally), Harang auroras (hook-shaped auroras with an opening to the west), and diffuse auroras (large patches of aurora with fuzzy edges). The student will survey 3-6 months of auroral images and record the times when each type of auroras occurred.
The work can be done on any laptop/desktop that is connected to the internet.

**Contribution.** Labeled auroral images constructed by the student will be used to train the machine so that it can automatically classify auroral images in unseen or future data. Since the training set directly determines the classifier parameters, the work done by the student lays an important foundation for, and also determines the quality of, the following classification. After the machine is tested and optimized, the results will be published in two journals, one in the field of space science, one in the field of machine learning. The results will also be presented in academic meetings. The student will be a coauthor of the papers/presentations.

**Outcomes.** The student will acquire understanding of auroral science and space science, and will know how to access, process, and interpret the latest space science data. The student will also gain basic knowledge of machine learning. If the student is interested, he/she can continue to participate in the project as a paid part-time intern after completing RCEU, where he/she will learn to conduct machine learning in collaboration with the computer science department at UAH.

**Student Selection Criteria**
The project is open to students at all academic ranks and from any academic discipline, although a physics background may facilitate a deeper understanding of auroras.

**Faculty/Research Staff Mentorship**
It is the Prof. Ying Zou’s goal to make this project an educational experience for the student. As seen above, the project has been designed to cultivate the student’s interest in space science, expose the student to cutting-edge science topics, and provide the student with hands-on experience on data analysis. She will provide direct mentorship throughout the program. A preliminary mentorship plan is listed in Table 1, and the actual execution will be adjusted according to the student’s needs, progress, and performance. She welcomes the student to ask questions, and will always be available through emails and appointments.

*Table 1. Preliminary mentorship plan offered by Ying Zou.*

<table>
<thead>
<tr>
<th>Week 1-3</th>
<th>Meet with the student 2-3 times/week to demonstrate how to analyze and interpret auroral images. Assign short homework to let the student identify auroras.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 4-9</td>
<td>Instruct the student to survey 3-6 months of auroral images, and classify and label various types of auroras. Meet with the student 1-2 times/week to check progress and answer questions.</td>
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<tr>
<td>Week 10</td>
<td>Guide the student to summarize the findings and coach on academic presentation.</td>
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