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An integrated aurora image retrieval system: AuroraEye

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ABSTRACT

With the digital all-sky imager (ASI) emergence in aurora research, millions of images are captured annually. However, only a fraction of which can be actually used. To address the problem incurred by low efficient manual processing, an integrated image analysis and retrieval system is developed. For precisely representing aurora image, macroscopic and microscopic features are combined to describe aurora texture. To reduce the feature dimensionality of the huge dataset, a modified local binary pattern (LBP) called ALBP is proposed to depict the microscopic texture, and scale-invariant Gabor and orientation-invariant Gabor are employed to extract the macroscopic texture. A physical property of aurora is inducted as region features to bridge the gap between the low-level visual features and high-level semantic description. The experiments results demonstrate that the ALBP method achieves high classification rate and low computational complexity. The retrieval simulation results show that the developed retrieval system is efficient for huge dataset.

1. Introduction

Aurora is a permanent feature of the earth environment. It constantly changes in brightness and shape around the earth's north and south geomagnetic poles. People showed great interests in aurora research even as early as 17th century. Modern scientists discover that aurora is produced by the collision of charged particles from earth's magnetosphere and solar wind [1]. The traditional data analysis on aurora utilizes measurements of physical properties, e.g., electron density, solar wind speed and etc. [2]. These quantitative characteristics are often used in analyzing plasma processes in the magnetosphere and the ionosphere. In fact, beside the properties above, the luminance and the form of the auroras are also important characteristics for aurora research. With the digital all-sky imager (ASI) emergence in aurora research, images captured from the ASI play a significant role in studying auroral phenomena [3]. Different appearances of aurora contain different physical meanings. The structures of auroras which vary in shape, position and luminance correspond to homologous dynamics process in the magnetosphere and have abundant semantic information. The mechanisms which lead to temporal and spatial structure in aurora are the subject of intense study, and so optical observations of the aurora are of the fundamental importance in this field [2].

Static aurora image classification is the basis for aurora research. Early aurora classification is manually implemented by experts with naked-eye. In 1955, Carl Stormer [1] classified aurora into three categories, i.e., forms with ray structure, forms without ray structure and flaming aurora, which was the first attempt of aurora classification. Akasofu [4] manually divided the aurora into four categories along the equator direction in 1964. Hu et al. [5] sorted the aurora into four types in 1999, which are band, corona, active surge and sun-aligned arc. Until 2004, Syrjasuo and Donovan [2], Syrjasuo et al. [6] introduced the machine vision technology into aurora research and identified three distinct categories of auroral appearance in the all-sky images as Fig. 1:

- *Arcs*: one or more auroral arcs.
- *Patchy auroras*: irregular patches of auroral intensity visible in the whole field-of-view.
- *Omega-bands*: brighter shapes that resemble those seen when an Omega-band is visible in the field-of-view.

This paper focuses on the study of diurnal patchy auroras. Since diurnal patchy auroras are the main form of aurora at magnetic noon, which reflects the dynamics process of the interaction of solar wind and earth magnetosphere. The study of diurnal patchy auroras is of great significance to analyze the ionosphere and its dynamic features [5,7]. According to their different characters, they are classified again into three subcategories [8] named *drapery*

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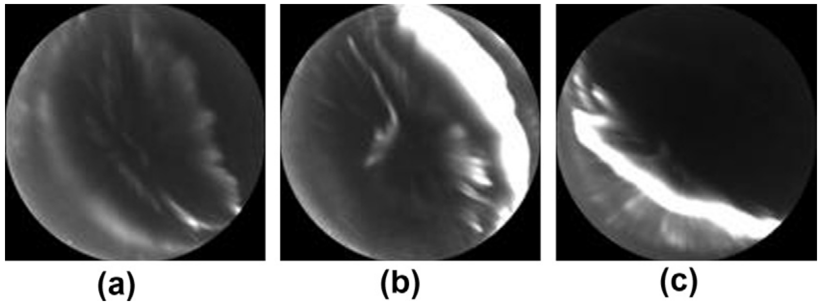

Fig. 1. Three distinct categories of aurora: (a) patchy auroras, (b) arcs, and (c) Omega-bands.

corona aurora, *radial corona aurora*, and *hot-spot aurora*, respectively as showed in Fig. 2.

- *Drapery corona aurora* presents multiple, east–west elongated rayed bands with weak emission at 557.7 nm and looks like waving curtains layer upon layer.
- *Radial corona* shows radial structure with weak emission at 557.7 nm, but strong at 630.0 nm. Rays in ASI image radiate from the zenith to all directions and change rapidly.
- *Hot-spot aurora* is a complex auroral structure, including radial structures, transient brightening rayed bundles, spot and irregular patches with intense emission at 427.8, 557.7 and 630.0 nm.

The patterns of the three subcategories of patchy auroras are significantly different from arcs and Omega-bands. The Omega-bands look like a kind of special arc shape and is a small quantity of aurora images. Since there are only 2 Omega-bands from 13,225 images in the database, so we combine arcs and Omega-bands into one category named multi-arc. Thus there are four main categories, i.e., drapery corona, radial corona and hot-spot and multi-arc auroras.

The emergence of digital imaging technology makes it possible for researchers to acquire more and more aurora data. However, the wide application of aurora imaging systems results in mass data which is difficult to manually process. Therefore automatic analysis and retrieval of aurora images in the huge dataset has evolved into an essential topic. The research of content-based image retrieval has been very active in recent years [9–13,29–34], yet only a few applications for auroral image retrieval are developed. In 2004, Syrjasuo implemented the content-based retrieval of auroral images based on shape features [14] and then merged the relevance feedback technology into the retrieval system to search for one rare auroral form ("north–south structure") [15]. Both of the retrieval algorithms are based on shape feature and suitable for the aurora images with clear shape, like arcs. But our goal is to retrieve the diurnal patchy auroras with extremely complicated shape which is difficult to describe. For example, the auroral light of radial corona aurora looks like rays emitting from one point and has no apparent shapes. Therefore only shape properties are not suitable for all kinds of aurora images. Through the observation of the aurora images, it is found that different kinds of aurora have different textures. For example, the texture of drapery corona aurora behaves layer upon layer like waving curtains and is very regular, whereas multi-arc composed of one or more bright bands stochastically makes the texture changing acutely. So the texture characteristics are employed to describe aurora images in our research.

The integrated aurora image retrieval system, called AuroraEye is developed based on several processing modules including features extraction, image classification, and image retrieval. In the system, the aurora image is represented by two kinds of information from different aspects. One of them is the metadata which includes the date when aurora occurs, category to which the aurora belongs and the radio band in which the aurora is captured. The other kind of information is the features which are extracted from the aurora image to describe the low-level characters of image. Gabor [16,17] and LBP [18] are used to extract the macroscopic and microscopic texture information from the aurora image, respectively. Considering the global characterization alone cannot ensure satisfactory retrieval results, the features of localized region of the aurora image are integrated in the system.

2. The overview of AuroraEye

Fig. 3 presents the architecture of the developed aurora image retrieval system, AuroraEye. It consists of a graphic user interface, three databases, and four subsystems. The function of major components of the system and the techniques applied to corresponding subsystem are detailed below Fig. 4.

The image preprocessing subsystem preprocesses the images off-line. The images of AuroraEye come from Chinese Arctic Yellow River Station, which are 3-wavelength (427.8, 557.7 and 630.0 nm)

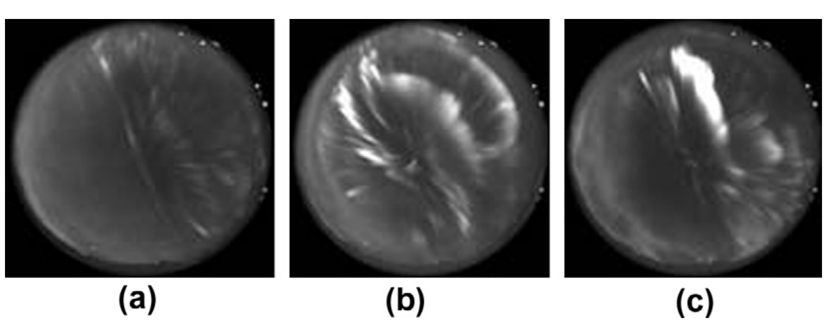

Fig. 2. Three subcategories of patchy auroras: (a) drapery corona aurora, (b) radial corona aurora, and (c) hot-spot aurora.