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DATABASE AND DATA SEARCH SYSTEM USING 'KANSEI' WORDS FOR AURORA IMAGE FILES OF DMSP SATELLITES

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Abstract: Image Database Systems usually have some keywords selected by human decision. In recent years, it has been an interesting problem to develop a method by which shapes, colors and contents for a specific image from image files are recognized automatically through image processing. Furthermore, it becomes important to determine properly the keywords representing impression of images, that is, 'KANSEI' words. We try to construct a database and data search system of the DMSP satellite auroral image files.

At first, an index file including information such as file name, size, date and geometric feature of images is created through image processing. The impressional items for auroral shapes such as brightness, position, and impression are derived by a coordinate conversion method so called the 'KANSEI' space method. The system contains about 100 image files and the index file. A specific image data is searched with the index file and the conversion method of 'KANSEI' words.

1. Introduction

Image databases may be regarded as storage and retrieval systems where a large amount of image are created, indexed, modified, searched, and retrieved. The image databases of which keywords and indexes are selected by human decision have become increasingly popular. Image database systems have been matured in association with multimedia systems. Office filing systems and medical image systems are the examples of these databases. They have the keywords and interactive queries selected manually. The user inputs and indexes the various features and/or terms of image data. At present stage, however, it becomes important to develop automatic indexing of an image data (for example, shape, color, content and impression).

KUROSAWA and HONG (1991) proposed 'similarity retrieval' of image by using shape features. NAGASAKA and TANAKA (1992) studied automatic indexing and searching for video data. Independently, SMOLIAR and ZHANG (1994) and ZHANG *et al.* (1995) proposed automatic parsing and indexing of video data. They noticed the topological differences between video frames and presented the method for automatic indexing. But they didn't refer to the impressional contents of images.

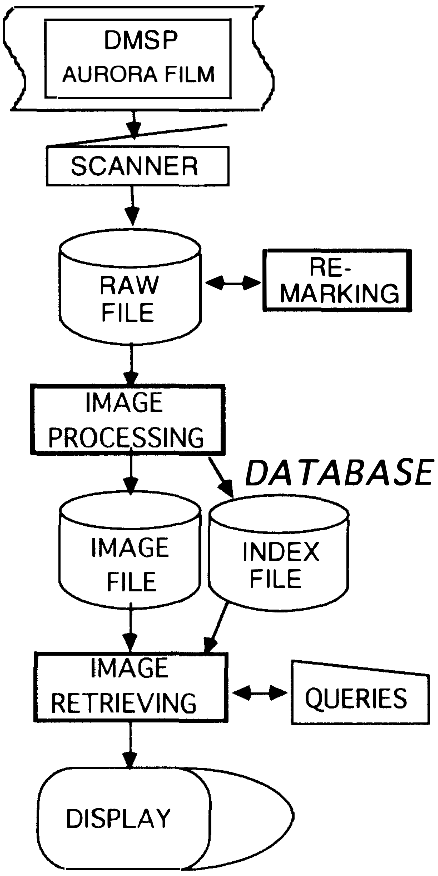

Fig. 1. Block diagram for DMSP aurora image database.

KURITA *et al.* (1992) studied 'sense retrieval' on images. They used impressional words to retrieve pictures from a picture database by the canonical correlation analysis. KHOSHAFIAN and BAKER (1996) refered automatic content retrieval systems. TAMENAGA *et al.* (1996) proposed a database system using 'KANSEI' words.

An image database system such as auroral images needs some keywords related to physical features. These keywords are usually absolute values of position, scale and shape and so on, which are represented in degree, km or arc. Choosing suitable values of the keywords to retrieve the database is rather difficult at the beginning of use. In contrast to the parameters with absolute values, impressional words are basically correlated to relative values, and make possible to optimize ranges of values. For this reason, it becomes easier to choose keywords in the data search system using 'KANSEI' words.

We propose an automatic indexing method for images and a retrieval system by the impressional space method. Figure 1 shows the block diagram for the DMSP auroral image database system. First, auroral films are inputed to disk files by an image scanner. The disk files are called as the raw file. Usually, texts and marks in the raw file are not clear, then re-marking process is necessary. Image processing reads the re-marked raw file, and makes image files and an index file. We call these files the image database. In many cases, it is possible, to select suitable queries for a specific image data.

2. The DMSP Satellite Auroral Images

The auroral image data come from Air Force DMSP satellites, which were in 99 degree inclination sun-synchronous orbits with altitudes ranging between 815 and 852 km,with the orbital period of about 102 min. The images result from a scanner system that relies on the forward motion of the satellite and a rotating mirror to provide each two dimensional image. Spatial resolution is about 2.8 km at subtrack. The scanner operates in the spectral region 400–1200 nm, peaking near 800 nm as determined by calibration against the solar spectrum, over a dynamic range spanned more than six orders of magnitude. The width of the data frames is 2958 km.

The layout of the data frame is shown in Fig. 2. Each data frame contains the system information area and image area. The system information comprises the ephemeris information and the system marks.

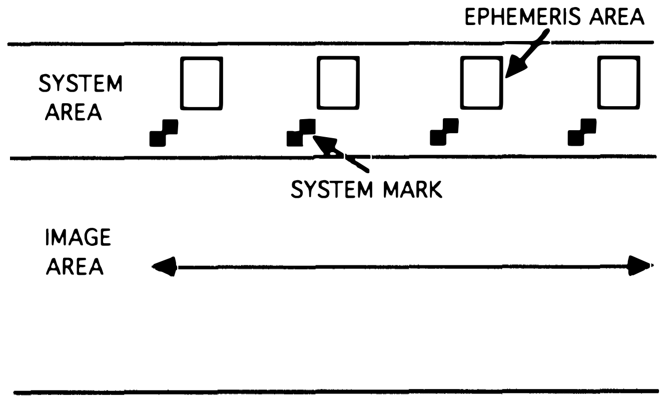

Fig. 2. DMSP auroral file format.

The ephemeris information consists of the Universal Time, date, geographic longitude and latitude, and orbit number. The center line of image area represents the subtrack of the satellite across the image. Intersection of subtrack line with line projected at right angle from the system marks indicates the point, for which the ephemeris information is given. Spacing of the system marks represents two minutes of time.

The auroral image data are archived on 35 mm microfilms. At the beginning of each reel of microfilm, two universal grids (Earth's surface and 110 km) are provided. From these grids, one may obtain the geographic coordinates of auroral features as well as those of any ground-level feature on image such as city lights, oil flares, moonlit snow and ice etc. Each grid has been corrected for foreshortening along the edge of the image. In the present database system, the universal grid at the Earth's surface and a world map are provided to be overlaid on the auroral images to determine geographic coordinates of any auroral feature as well as of any ground-level feature.

The DMSP satellite auroral image data are digitized by using a film scanner connected with a Macintosh personal computer. The files have the 256 gray scale, and the file size is about 1.2 MB (1500 times 800 pixels). The image data files are copied onto a UNIX workstation in the PGM, PPM format. As shown in Fig. 2, the ephemeris information (the Universal Time, date, geographic longitude and latitude) at two or three system marks on a frame are enlarged by using a graphic application software. These data are used to give some parameters of index files as will be discussed later.

3. Image Processing of Aurora Image Data

In the image processing, the original image data are put into files and a topological shape of the images such as an arc and a straight segment is detected. Then, the topological shape is indexed to give appropriate keywords to the auroral features. The topological shape and the keywords are stored in the index file. Figure 3 gives a brief overview of various steps involved in the image processing system.

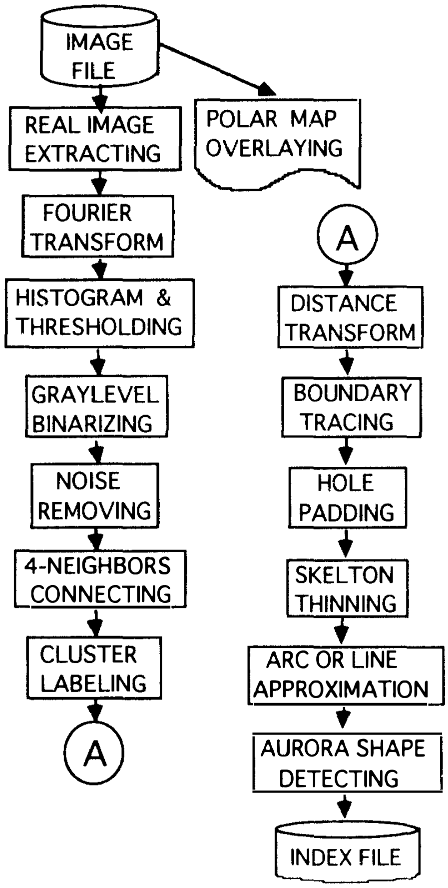

Fig. 3. Image processing.

Each step of the image processing is described in the following.

(1) Image area extracting

An auroral image data contains a system area and an image area as mentioned in the Section 2. Only the image area is used for the image processing. Some of the image area have dark vertical stripes or gray big holes, which are the noises for the processing. These noises should be removed from the image area to extract the real image part. For this purpose, we use the scanline method which provides intensity at pixels on each horizontal line. The noises are detected as parts of lower and/or higher values beyond the specified limits of the intensity curve and as parts of steep gradients of the curve. The size of the extracted image area is about 1000–1400 pixels times 600–800 pixels.

(2) Fourier transform

Fourier transform is convenient to analyze spatial frequencies of aurora. In the present analysis, we derive the Spatial frequency with the maximum amplitude. The two-dimensional fast Fourier transform (FFT) is suitable for the image size of the power of 2. The nearest size from the center of the image area is 1024×512 pixels. But this size is too large to process for personal computers, because the computational time of the FFT is proportional to the third power of the dimension of the image area. The image size of 128×64 pixels is chosen because it is suitable to the FFT analysis by using the computers such as a DOS/V personal computer or an UNIX workstation.

(3) Histogram and thresholding

The histogram of intensities in an image gives a global description of the general appearance and a threshold for binarization of the image. If the histogram shape has two peaks (bimodal), the threshold T is set to the value at the valley between the two peaks. In the cases of flat or rippled histograms, we employ an integral method. The integral metod determines a threshold value giving T percent of the dark areas in the histogram.

(4) Graylevel binarizing

Binarizing is a straightforward way to analyzing images. In most cases, graylevel images have too much information of shapes. By thresholding, the graylevel images are converted to the black and white images. The black parts usually show lands and seas and the white parts auroras, city lights and noises.

(5) Noise removing

After binarizing, an image has a number of noises such as small dots of city lights. Usually, these noises have smaller than 4×4 pixels or a 20 perimeter length. We use the 6×6 noise filter to remove the noises. Neither narrow and long noises nor noises larger than 6×6 pixels, however, can be removed by this filter. Therefore, the noise removing is done again after clustering.

(6) 4-neighbor connecting

The connectivity of two adjacent pixels is known as the 4- and 8-neighbor (connection). The 4- and 8-connection do exist. The noise removing causes to change the connectivity. The 4-connection is suitable for the following processes. If the 8-connection exists, some troubles may occur in the processes of the boundary tracing and the skeleton thinning, and the processes become more complicated. When we detect the 8-connection, we change it to the 4-connection.

(7) Cluster labeling

A cluster is defined as the connected white components. These components are candidates of aurora. Generally, clustering is done by the scanline algorithm and a discontinuous number is labeled to each cluster. In order to sort all the clusters in descending order of each cluster size, they are renumbered. Then small clusters are removed as noises.

(8) Distance transform

Distance transform gives the minimum distance from a boundary pixel to the innermost pixel. From the ratio between the minimum distance and the perimeter's length derived from the process (9), the shape of a cluster is inferred. The shape like a circle is not considered to be an aurora but a noise such as city lights.

(9) Boundary tracing

The border's length of a cluster is used to decide the shape of a cluster as mentioned above. Boundary tracing gives the border points and the border's length. The length and the direction of a cluster are determined from the positions of the farthest two border points.

(10) Hole padding

Big holes which are not removed as noises sometimes remain in a cluster. If a cluster has holes, the skeleton thinning process (11) becomes more complicated and need more time to spend, and more than one skeletons are obtained for one cluster. In order to avoid the complexity, every hole should be padded with the white pixels before the process (11), which simplifies the skeleton thinning process.

(11) Skeleton thinning

A skeleton is the thinnest structure of a cluster. The shape of each skeleton is considered to represent the shape of the clusters. We use Hilditch's thinning algorithm. Through the thinning process, a number of twigs should appear around the skeletons.

The twigs should be removed correctly to get the most suited skeleton for each cluster. At present stage, there is no ultimate method to avoid the difficulty about the twigs in extracting the shape of the clusters. In this study, among paths connecting any two pixels at the end points of the skeletons and the twigs, the longest one is selected. The processes (8)–(11) are done for each cluster, respectively.

(12) Arc or line approximation

All the skeletons are approximated by an arc or by a line through the process of a curve fitting. We use the 'minimax approximation' method which was developed by one of the authors (Y. KUROZUMI). The approximation error can be easily estimated by this method. Finally, the coefficients of the equations for an arc or a line are obtained.

(13) Aurora shape detecting

By the image processings (1)–(12), we can get various pieces of information about the auroral images. The information is obtained in the form of the text data and is indexed for data retrieving. The indices consist of information of the Fourier transform and that of the topological shape. The image size, median value of histogram, histogram shape, number of auroral components, area of aurora, number of noise components, area of noise, position of aurora, and global shape are indexed. From the system information, the coordinates on a frame of the two selected points are indexed. One is a pole, and another is the point of 80 degree in geographic latitude and 0 degree in longitude. These indexes are stored in one record per an image in the index file.

4. 'Kansei' Data Retrieving with the 'KANSEI' Space Method

This auroral database system has a number of image files and the index file. All of these are the sequential files. The index file contains all of the searching keywords and the same file names as those of the image files. The file names as well as the geographical data such as date, latitude and longitude included in the index file link the individual image files with the index file. Data retrieving is not much complicated. By querying some keywords and their ranges, all records in the index file are searched and the corresponding records containing the same keywords and

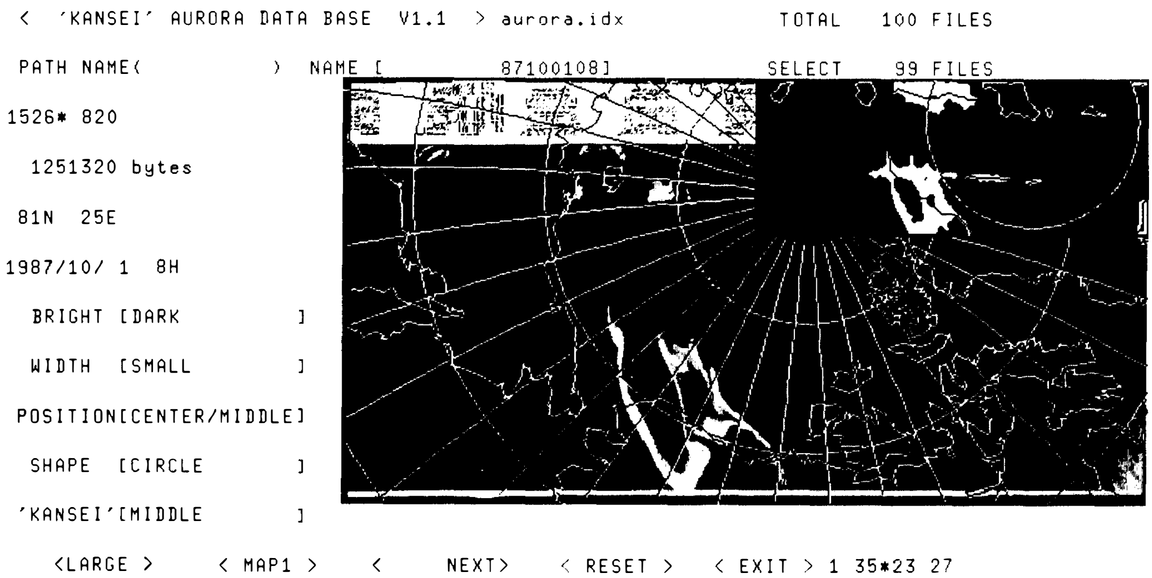

Fig. 4. An example of the query window.

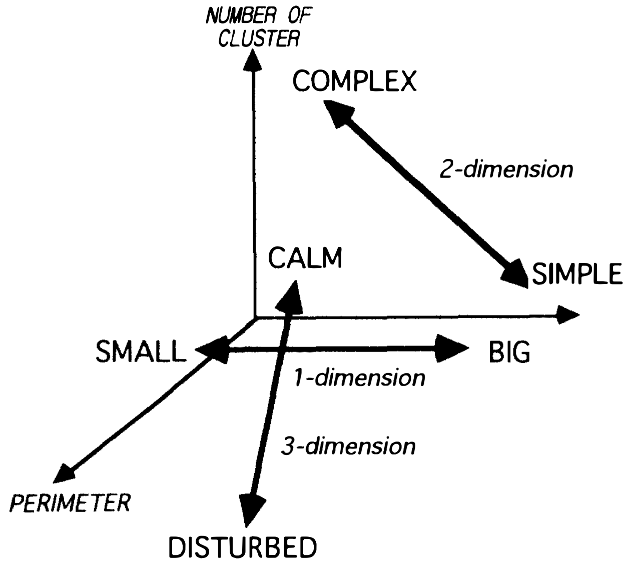

Fig. 5. 'KANSEI' space.

allowable values as queried are found.

Figure 4 illustrates a query window of our retrieving system for the image data. The searching method is incremental. When the queries are inputted, the searching system starts and the total number of hit records are displayed. The query items consist of the two kinds of contents. One contains the geographical items such as name, size, date, latitude and longitude. Another has impressional items relating to auroral features such as brightness, width, position, shape and the 'KANSEI' word.

Conversion from the topological items to the impressional ones is rather complicated, since it is not so easy to convert topological values of auroral features to appropriate impressional words. For this purpose, we propose a coordinate conversion method called the 'KANSEI' space method. The 'KANSEI' words expressing impression for the auroral features are defined on the 'KANSEI' space constructed of the relevant topological axes. Figure 5 illustrates a schematic diagram of the method.

In one dimensional space, the 'KANSEI' words 'small' and 'big' are related to the area size of aurora. The one-dimensional conversion method is well accepted and used in many applications including fuzzy databases. This method can be extended to a case of the multi-dimensional space. In the case of the two dimensional space, the words 'complex' and 'simple' are related to the ratio between the number of clusters and these area size. Many and small clusters are expressed as 'complex', and few and big clusters as 'simple'. In the three dimensional space, we select five 'KANSEI' words, namely, 'very calm', 'calm', 'little disturbed', 'disturbed' and 'very disturbed' in relation to auroral activity. In the three dimensional space, the 'KANSEI' words are associated with the three topological values, that is, the number of clusters, the area size and the length of clusters' perimeters. The word 'very calm' represents few and 'small' aurora with the small ratio between the perimeter's length and the area size.

5. Discussions

The image processing for auroral data is complicated, and it needs a considerable amount of calculations. It needs about five minutes of CPU time per an image by a DOS/V personal computer or a Sun workstation. To avoid this, we constructed an index file linked with the image file. As discussed above, the index file has a simple structure and can be searched promptly. We chose the incremental search that starts searching as soon as every query is given. As a result, we will be able to search an image file from up to 10000 files by the incremental and conversion method.

In our database system, characteristics of the aurora such as position, shape and area size are derived automatically. The impression for the auroral features is indexed by the five 'KANSEI' words. The 'KANSEI' words such as 'calm' and/or 'disturbed', however, do not really correlate with auroral activities. Morphology of the aurora is rather complicated. Characteristics of auroral features are classified by National Oceanic and Atmospheric Administration as follows; faint homogeneous arc, faint homogeneous diffuse and discrete arcs, bright discrete arcs and bands, bright or very bright auroras with general arc of band-like appearance, bright or very bright auroras without distinct arc or band-like structure. It is very important for auroral studies to determine the 'KANSEI' words representing the complex feature of the auroras.

The auroral images in the raw files are given in the geographic coordinate. From the view point of the auroral research, it is useful to transform them into those in the geomagnetic coordinate. The transformation will be performed by an image analysis using the 'Morphing' method and something like that. It is also expected to link the optical image data with the particle data obtained by the DMSP satellites. In the near future, the database system of auroral images will be extended to link with the database of the particle data written in the same format as the image data.

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