P1.2 A COMPUTER VISION SYSTEM TO ANALYSE IMAGES OF LIGHTNING FLASHES

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1. INTRODUCTION

A recent study showed that, in 2001, more than twenty people were hit, directly or indirectly, by lightning strikes in summer time in the vicinity of São Bernardo do Campo (SBC), Brazil[1,2,3]. This region presents a high level of lightning activity and density, with 6.7 lightning flashes per km^2 occurring each year[4]. According to CEMIG – a company that generates and distributes electrical energy in Brazil – about seventy percent of damages on transmission lines and thirty percent on distribution lines are due to electrical discharges[5].

In addition to these high rates of incidents, lightning discharges also reflect the behavior of thunderstorms and can indicate the stage of cloud's electrification as well as the storm's severity[6].

One way to obtain information about the general behavior of thunderstorms is through the monitoring of lightning flashes recorded by video camera. Flash events show the temporal and spatial evolution of convective cells, allowing the visual identification of thunderstorms and its electrical discharges.

This paper proposes the development of an automated system to analyze, using computer vision techniques, the lightning flash images occurring in the vicinity of SBC. Lightning events are identified and classified by the system, providing information about the thunderstorm that qualifies and validates the data of electromagnetic field sensors also in operation at the University of FEI. When united, the resulting data allows a complete characterization of monitored thunderstorms.

2. DATA COLLECTION CAMPAIGN

A data collecting campaign occurred during the summer period in Brazil, from November 2007 to April 2008. Seven video cameras, disposed in a 360º loop, recorded continuously the weather activity in SBC throughout the campaign.

Besides the video information, the local weather monitoring system possesses an electric field mill sensor (EFM) and a flat plate sensor (FP), both developed at the University of FEI and synchronized in time by GPS.

External data, such as satellite images and commercial meteorological sensors, are also used in order to validate the local monitoring and improve its precision.

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3. THE COMPUTER VISION SYSTEM

With the objective of extracting information contained in lightning video sequences, obtained through the local weather monitoring system, a software is being developed using computer vision techniques.

Built in C++ language with the help of some functions contained in the OpenCV library[7], the software indentifies the lightning flashes and classifies each lightning stroke into two categories: vertical flash (VF) and horizontal flash (HF). These main categories will be used to identify cloud-to-ground flashes, intracloud flashes and air discharges in future studies.

Structurally, the computer vision system consists of a pre-processing stage, followed by segmentation and classification stages. Each stage is subdivided into basic blocks, as shown in figure 1.

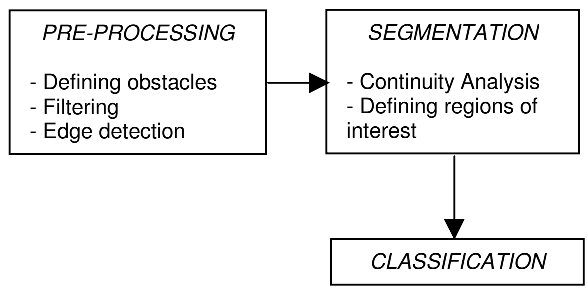


Figure 1: Block diagram of the proposed computer vision system.

3.1 PRE-PROCESSING STAGE

The first part of the pre-processing stage aims to define obstacles in the video image, such as buildings, threes and other fixed objects, in order to reduce the domain of analysis. The obstacles are manually selected by the user, and this process is done only once for each camera since all the video monitors have fixed positions and orientations.

In addition to the obstacles, the horizon line is also defined at this point through an analogous process. Stored as a vertical coordinate, the horizon line information is used later at the classification stage. Figure 2 presents both obstacles and the horizon line defined in the image of one sample of video camera.

A median filter is applied in all the video sequence to reduce noise, but this process still manages to maintain a good contrast level at sharp transitions that often represent contours of objects[8].

Figure 2: Image of a video camera. The red rectangles define obstacles and the white line defines the horizon line.

Finally, the edge detection block closes the pre-processing stage with the objective of making the contour of the lightning flashes more salient. This block assumes that, after the subtraction of obstacles and the whole area below the horizon line, all abrupt transitions in the intensity of the resulting image are lightning strokes.

The edge detection methodology is based on Sobel's morphological operator[9] and returns the intensity of image's gradient as well as its direction, making possible to decompose the resulting vector in the horizontal and vertical axis. This characteristic of Sobel's operator, easily implemented using OpenCV's library, is the foundation of two parallel processes that feeds the segmentation stage.

The first process uses the resulting vector of Sobel's operator to calculate which points of the image are discontinuous simultaneously on the horizontal and vertical directions. This process returns high values of intensity for a given point when that point presents high levels of discontinuity in both directions.

The second process uses the same vector to calculate which points of the image are discontinuous in the horizontal or in the vertical direction. This process returns high values of intensity for a given point when that point presents a high level of discontinuity in any direction. Figure 3 shows the result of these two processes applied to a lightning image.

Both processes are submitted to a fixed threshold that defines white, or one, as a discontinuity point and black, or zero, as a continuity point. The binary images are the output data of the pre-processing stage.

3.2 SEGMENTATION STAGE

The first part of the segmentation stage is a continuity analysis, which begins by involving each discontinuity point with a border of white points. This helps to connect continuous areas and lines that could have been disconnected at the edge detection stage or at the thresholding stage.

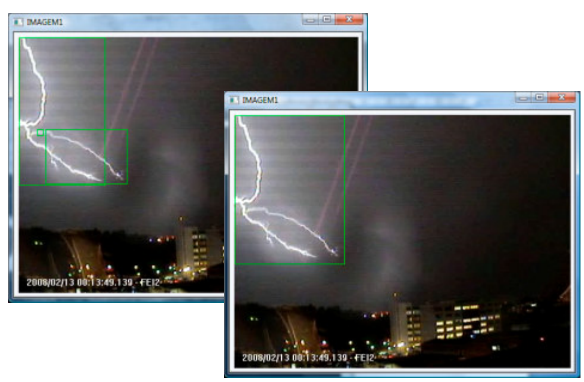
(a)

(b)

(c)

Figure 3: (a) A lightning discharge occurred at the University of FEI in 2008-02-13; (b) the lightning flash image obtained through the first process; (c) the lightning flash image obtained through the second process.

The reinforced binary images are subjected to a contour detection process. At this point, regions of interest (ROI's) are defined as the smallest rectangle containing all points of a given contour. Next, an algorithm mixes superposed ROI's that eventually remained disconnected, and also discards ROI's that are too small to be a lightning stroke. Figure 4 presents the defined ROI's of the lightning image of figure 3.a.



(a) (b)

Figure 4: (a) Independent ROI's of figure 3.a; (b) Mixed ROI's of figure 3.a.

3.3 CLASSIFICATION STAGE

The system's last stage is fed by the mixed ROI's defined at the segmentation stage. It is important to remember that, until this point, all the algorithms are executed in both images generated at the edge detection stage (figures 3.b and 3.c). On the other hand, to make the lightning classification it is necessary to select the best process for a given image.

A decisional hierarchy chooses the process that has the smallest number of independent ROI's in each video frame. In case of a coincident number of ROI's, the process that presents the largest integrated area of ROI's is chosen.

The classification process uses the horizon line information to make a comparison among the lightning contours. In case of one or more points of the lightning contour intersects the horizon line, the lightning is classified as a VF. In all the other cases, where the contour line does not intersect the horizon line, the lightning is classified as an HF.

4. DISCUSSION OF RESULTS

The intensity of light and the contrast characteristics of electrical discharges associated with the background image are the fundamentals on which this system's development is based. In fact, lightning discharges possesses random forms, imposing great limitations on its comparison to or approximation by other known forms and shapes.

At the pre-processing stage, the filtering process is necessary in the vast majority of picture frames, but even when it is not mandatory the final result is not negatively affected by its application.

Still at the pre-processing stage, the edge detection process is the heart of ROI's definition. Therefore, we chose to separate it into two parallel processes, exclusively for edge detection, to improve its robustness. The first process showed a good immunity to noise, but also proved to be inefficient in the detection of distant and ramified lightning flashes. In contrast, the second process showed greater precision in the detection of distant and ramified lightning flashes, but was also a little more sensitive to noise.

At the segmentation stage, the process of continuity analysis helps to connect the resulting points of the edge detection stages, aimed at the extraction of a continuous lightning contour. This process, alone, is not sufficient to connect all the points of a lightning flash, so the following algorithm mixes the superposed ROI's extracted from the lightning flash contours. The series execution of both processes grants a good connection level of all edge points.

Finally, the classification stage uses the contour of each lightning flash and the horizon line information to label each flash into two main categories: horizontal flashes and vertical flashes. It is important to clarify that these classifications are generic, done only to differentiate the lightning discharges that strikes the ground. In each category, a more precise classification system is being developed.

5. CONCLUSIONS

At the current state of development, the system is obtaining reliable results on the segmentation of the lightning channel from the background image and on the classification of the segmented images into two primary categories.

At the pre-processing stage, although the obstacles and the horizon line definitions are being made in a supervised way, with the interaction of a user, the automation of this process would not result in a practical gain when considering the fixed position and the small number of monitoring cameras at the University of FEI. As a future proposal, a machine learning approach could help to differentiate the fixed background from the interesting image data.

The conclusion of this project will allow the expansion of the current covering area of the local monitoring, still limited by the high volume of video information to be manually analyzed. Other proposal implemented at the University of Fei regarding the optimization of video data uses a commercial camera to record omnidirectional videos with the help of a convex mirror[10].

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