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DATA SIMULATION FOR THE LIGHTNING IMAGING SENSOR (LIS)

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This project aims to build a data analysis system that will utilize existing video tape scenes of lightning as viewed from space. The resultant data will be used for the design and development of the Lightning Imaging Sensor (LIS) software and algorithm analysis. The desire for statistically significant metrics implies that a large data set needs to be analyzed. Before 1990 the quality and quantity of video was insufficient to build a usable data set. At this point in time, there is usable data from missions STS-34, STS-32, STS-31, STS-41, STS-37 and STS-39. During the Summer of 1990 a manual analysis system was developed to demonstrate that the video analysis is feasible and to identify techniques to deduce information that was not directly available. Because the closed circuit television system used on the space shuttle was intended for documentary TV, the current value of the camera focal length and pointing orientation, which are needed for photoanalysis, are not included in the system data. A large effort was needed to discover ancillary data sources as well as develop indirect methods to estimate the necessary parameters.

Any data system coping with full motion video faces an enormous bottleneck produced by the large data production rate and the need to move and store the digitized images. The manual system bypassed the video digitizing bottleneck by using a genlock to superimpose pixel coordinates on full motion video. Because the data set had to be obtained point by point by a human operating a computer mouse, the data output rate was small. The loan and subsequent acquisition of a Abekas digital frame store with a real time digitizer moved the bottleneck from data acquisition to a problem of data transfer and storage. The semi-automated analysis procedure was developed using existing equipment and is described below. A fully automated system can be described in the hope that the components may come on the market at reasonable prices in the next few years. The fully automated system would control an external videocassette recorder by reading a time code on the tape then capturing a sequence of frames, transfer the digitized images to the computer memory and then extract the lightning data using the LISO algorithm. If the system were fully automated, it would rewind the video tape and capture the next section of data until several minutes of data were processed. The ideal system would also capture data encoded in the vertical blanking interval of the original video, decode these pixels to determine GMT and camera motion. The ideal system would also have sufficient multitasking capacity to update the orbiter position on a second by second basis.

Semi-automated Analysis Procedure

Several aspects of video analysis need to be addressed. Video data is produced rapidly. Thirty frames are recorded in a second but a low cost digitizer may need five seconds to digitize a single frame and it would consume the better part of a minute to label the file, store the data and use the mouse to get pixel location data at several features in the image. Each second of data produces about 10 Megabytes of monochrome digitized image data and could take about a half hour to digitize. A "real time digitizer" (1/30 second for a frame) speeds up the digitizing work but aggravates the data storage problem. One way to avoid the data storage problem is to superimpose a crosshair on the video and read data points without ever digitizing the images. That was the idea behind the manual analysis method. The automated method digitizes every frame in a sequence then discards pixel information not related to lightning. A typical video sequence would be of the order of one hundred seconds in length. The digitized images files for one hundred seconds would contain about 1 gigabyte of data which would exceed the throughput of existing equipment. One hundred seconds of data would have to be captured as many shorter sequences. If one manually started and stopped the VCR some overlap of the start and end of the short sequences would be necessary to be certain there were no gaps in the digitized records. This would produce a large volume of duplicate data that would have to be sorted and discarded.

The semi-automated analysis procedure starts by linking a Sony 3/4 inch tape recorder to the Abekas input and connecting the channel 2 audio (SMPTE code) output to the input of a SMPTE time code generator to regenerate a control signal to start the frame capture sequence. In order to record frames with accurate start and stop frames, the SMPTE code for the start frame must be entered into the ABEKAS as well as the number of frames to capture. After the tape is started, the time code generator is reset in order to slave the generator to the video source. The Abekas digital frame store will automatically capture several hundred frames. The starting frame for the next segment would be hand calculated and the recording process repeated until the entire video scene was captured. It is necessary to move the data from the Abekas via ethernet to a computer to proceed with the analysis. Paul Meyer has written a utility LISGRAB that moves a sequence of image files over ethernet and stores them on the Stardent in sequentially labeled files.

Level 0 data will be raw instrument data at original resolution, time ordered, with duplicates removed. This data will be downlinked from the LIS instrument. The LIS00 algorithm produces lightning data by extracting illuminated video pixels from a background as it scans a sequence of data files. This code reads one image file at a time and builds a background buffer that is the average of the last four valid background intensities for each pixel of interest. Data which exceed background and a threshold are not added to background but are sent to the output. The LIS00 output stream consists of the file ID (based on the GMT), video pixel X, Y and amplitude. Test cases will be used to determine the ability of simple, quick algorithms to separate lightning from nighttime background lights. Examples of interference include video noise introduced at the camera focal plane, the video downlink, the copying and digitizing process as well as aircraft beacons and explosions.

The output of LIS00 is sent to LIS0 which uses pan, tilt, altitude and focal length information to map the original oblique view video pixels into a nadir view with 10 km resolution. Because the higher resolution video data will map several pixels into the same 10 km resolution pixel the data will be sorted to remove duplicates. The output of LIS0 is a data stream consisting of time, pixel location and amplitude. This data is called imitation LIS level 0 data because the video data is at lower time resolution than the LIS level 0 data and the video oblique view produces data that would be out of view of the real LIS.

The LIS0 algorithm also removes duplicates by retaining the maximum value for a particular LIS pixel. Present LIS plans call for downlinking the background scene at fixed intervals. The background scene will be examined to verify the location and orientation of the platform as well as pixel calibration. Decisions are needed concerning the frequency of the background transmission, the source of this data (real time or averaged background), and whether to report this as part of LIS 0 data or store locally and discard. The background scene will be helpful in identifying optical events that are not produced by lightning. Optical pulses from cloud-free areas near cities can be discarded because they are generated by human activity.

LIS Level 1 data consist of the level 0 data stream packed with geo-referencing information and ancillary data. This data product will also contain a time stamp computation and calibration information. The LIS1 algorithm combines two data streams: the LIS 0 data stream and reference data from the platform. At present the content and format of the platform data has not been determined. Simulated time and location data will be generated to provide a data stream. Since LIS data will be asynchronous with respect to the orbital motion a decision is needed on whether to report platform data when there is no LIS data.

Level 1A data products are transformed values of full resolution instrument measurements. The data stream will consist of individual optical pulses with Universal time of origin, Latitude and Longitude of source, radiance of pulse and threshold setting. This data stream provides the most detailed set of calibrated data. Decisions are needed on the format of the output product.

Level 2 data consist of geophysical parameters located in time and space. The items of interest here are lightning stroke and flash identification. Optically, a single lightning flash is comprised of a series of discrete short duration optical pulses associated with energetic discharge processes occurring within a cloud. The individual optical pulses will be grouped to provide a single location (initial location) and starting time for a stroke. If another stroke is found in close time and spatial proximity, the combined event will be classed as a multistroke lightning flash. Other luminous events such as meteors, sun glint, explosions, strobe lights and search lights may have to be identified at this stage. It must be noted that not all optical events in a flash will exceed the LIS threshold and be detected. The most important derived parameter is the lightning flash rate. The platform will be in a polar orbit which limits the time of continuous observation of any point within the field of view to about two minutes. This implies that strokes occurring at a particular location must be averaged for an observation period. Decisions are needed about which location to report for a lightning flash that extends over several pixel locations. Since the flash extends over time a second decision is needed regarding the choice of time tag.

The primary task of the level 2 algorithm is to group optical pulses into strokes, group strokes into flashes and count flashes at a location. It is desirable to perform the initial grouping as the time sequential data stream arrives. After a particular location has passed out of view and the incoming data stream will no longer contain relevant data, then the final summary of the data for a particular location can be constructed. A preliminary look at the algorithm suggests that the classification could be done on the level 0 data stream using coordinates relative to the LIS instrument. After the optical pulses are grouped, the location and start time of a grouping could be computed using platform data. With the flashes identified, the level 1A data could be organized on a flash by flash basis rather than a time of arrival basis. This algorithm would be more efficient because the level 1A data stream is larger than the level 0 data.

Level 3 data products consist of LIS geophysical parameters mapped and time averaged onto a uniform Earth based grid. Standard level 3 products will be produced with spatial resolution between 0.1 degree and 2.5 degrees. The data will be accumulated to produce global pentads, monthly, seasonal, yearly, annual and interannual maps of lightning. LIS level 3 products will include maps and statistics of total optical pulses, total flashes, flash densities, radiant intensities, discharge type and flash duration as well as mean and extreme value statistics. Since these mapping and statistical function are common to most EOS instruments, the EOSDIS contractor is expected to produce a tool kit for consistent mapping and statistical treatment of many different data sets. The run time of these tools may be improved by producing the LIS level 1A data grouped by flash. The polar orbit provides for extensive overlap of the viewing area during successive passes of polar locations. Since the observing time enters into the statistical significance of the data the EOS contractor is expected to address this need for all instruments.