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Application of GEODSS to Detection of Earth-Crossing Asteroids

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APPLICATION OF GEODSS TO DETECTION
OF EARTH-CROSSING ASTEROIDS

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Abstract

The Ground-based Electro-Optical Deep Space Surveillance (GEODSS) System is discussed for use as a patrol system to discover new asteroids. The capability of the system potentially allows rapid imaging and data processing of approximately 4250 fields-of-view per telescope per night. A modification to the current artificial satellite detection algorithm can be used to automatically detect asteroids.

Nomenclature

AUX	Auxiliary Telescope
CMC	Cheyenne Mountain Complex
FOV	Field Of View
MAIN	Main Telescope
Pixel	Picture Element
PPM	Precision Positional Measurement
SIT	Silicon Intensified Target
SOI	Space Object Identification
USAF	U.S. Air Force

I. Background

The GEODSS System is a resource of the USAF Space Command and is part of the SPACETRACK Network. GEODSS consists of four optical sites distributed in longitude with combined 24-hour coverage. The system is primarily used to track artificial satellites beyond a 12000 kilometer radius from the center of the Earth. Types of observations performed include Precision Positional Measurements (PPMs) and Space Object Identification (SOI) radiometer measurements. These observations are sent over data communications lines to the Cheyenne Mountain Complex (CMC) in support of USAF satellite catalog maintenance. Other use of GEODSS has been to observe space debris.[1]

Each site has three telescopes and an interlinked combination of four computers which control the telescopes and cameras. A high degree of automation has been implemented in the site software.

Three sites have two MAIN telescopes and one auxiliary (AUX) telescope while one site has three MAIN telescopes only. Two camera scales are available: "zoomed" and "unzoomed". Each MAIN telescope is of Ritchey-Chretian design with 1 meter mirror and a zoomed or unzoomed circular field-of-view (FOV) of 1° or 2°. Each 0.4 meter AUX telescope is of folded Schmidt design with a zoomed/unzoomed FOV of 3°/6°. Field corrector lenses provide flat fields for the cameras.

A Silicon Intensified Target (SIT) tube with an 80 mm diameter target area is used in all GEODSS telescope cameras. These cameras operate in slow-scan or RS-170 video with a resolution of 832 by 832 pixels. Depending on zoom mode, pixel size is approximately 4 or 8 arc-seconds on a MAIN and 12 or 24 arc-seconds on an AUX. Camera integration times are programmable. They normally integrate for 300 msecs on the MAIN and 600 msecs on the AUX telescopes in slow-scan mode, which is the mode used for automatic detection and image processing. This allows a MAIN to reach magnitude 16.53 in a good sky, with some absorption due to Mt. Pinatubo dust, while an AUX can reach magnitude 13.28.[2] Increasing integration times to 2.4 seconds allows a MAIN to reach magnitudes fainter than 17.45 and an AUX to reach 15.28. RS-170 modes have been investigated with similar results.[1,3]

A GEODSS site is typically tasked by the CMC to acquire sets of observations on 300 to 500 artificial satellites per night. Depending upon weather, GEODSS successfully automatically detects and determines position for approximately

90% of the objects attempted. A slight modification to the current method used at GEODSS could be used for automatic asteroid detection as presented in the discussion which follows.

II. Discussion

A possible algorithm which can be readily implemented in GEODSS is described here. Figure 1 shows the formation of a composite frame of data similar to, but simpler than, what is currently done. This would be formed by "OR"ing a succession of camera frames acquired over an arbitrary period of time. After formation of the "OR" frame, pixel clusters are identified by examining each "on" pixel for other "on" pixels within a 5 X 5 array centered on the pixel under examination. If any of those pixels are on, a search is queued around those pixels. This continues until no neighboring pixels are found. The cluster so found is formed of N pixels having x, y and associated times. Sums of all x, y and time values are then formed for the cluster. The mean value of each is computed to form the centroid of the cluster.

Clusters are combined to form a super-cluster or "streak" by simply adding up the already determined sums of nearby clusters. An auto-correlation factor, which considers the chronology of the presence of pixels, is computed to indicate whether or not the cluster or streak is a true effect. That is, cluster pixels on the individual frames which are used to make up the "OR" frame must proceed from frame-to-frame in a constant direction with a constant speed. Clusters determined to be "false" are discarded.

GEODSS has an 80386 PC-based workstation which is used for system simulations at the System Programming Agency and special investigations at Site 1. This workstation is suitable for use to capture frames of data on disk for later

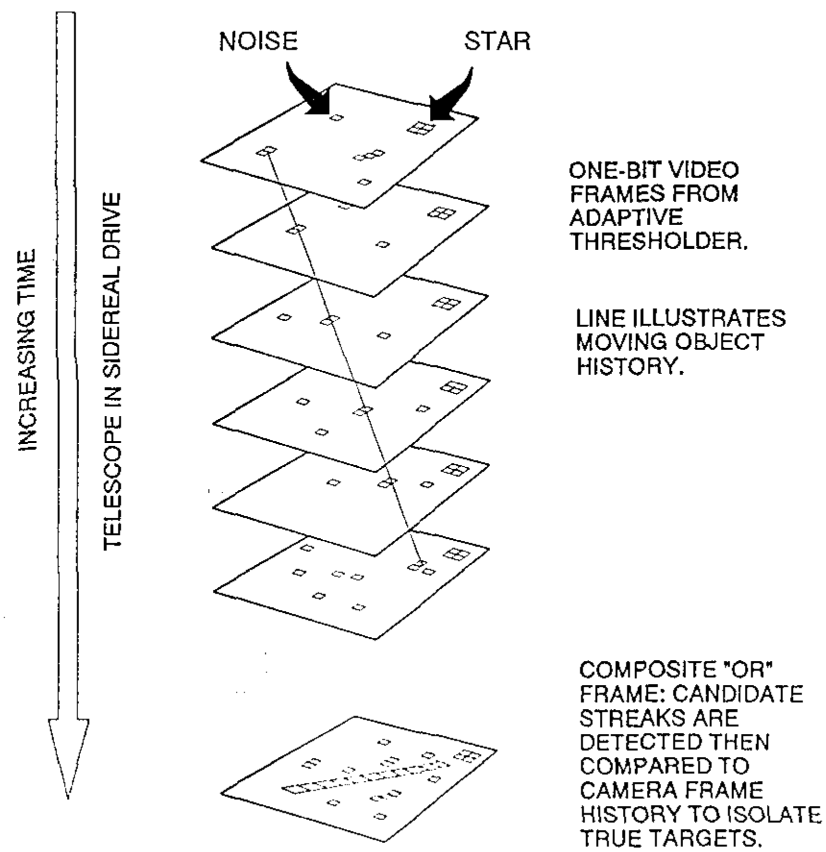

Figure 1. Streak Formation.

analysis. It contains an Imagraph HI*DEF video board with 1280 by 1024 resolution and a frame-grabber which is tied into the GEODSS camera.

With a 2.4 second frame integration time and telescope slew and settle rates of about 1 second (within 5° of current position) the hardware is capable of a maximum possible acquisition rate of about 8500 FOVs per telescope in an eight hour night. It is not unrealistic to expect half this acquisition rate might be obtained (4250 FOVs per telescope). Assuming the same field is visited eight times at half hour intervals, the effective rate would be about 530 fields. Table I shows the coverage capability of the various GEODSS telescopes and modes with this acquisition rate.

	FOV (deg)	Coverage (deg^2)
MAIN	1	416
MAIN	2	1665
AUX	3	3745
AUX	6	14985

Table I. Potential Sky Coverage of GEODSS Telescopes.

A special hardware adaptive thresholder allows formation of one-bit video above any set sky background threshold. This limits the amount of actual bytes of data since no grey scale is employed. Thus, 86,528 bytes are required for imaging an FOV. Combining this with the acquisition rate leads to a data storage requirement in excess of 367 megabytes per telescope on a maximum throughput night.

Actual detection of an asteroid would be accomplished by taking frames on a given FOV one-half hour apart for a maximum of eight frames or so. Image processing and data reduction would take place at any convenient time after acquisition. Besides the automatic software detection, animation can be applied for visual examination by successively flipping through the frames on the high resolution monitor.

GEODSS has high acquisition rates combined with relatively large FOVs attained by the use of SIT tubes. This suggests that the most effective use of GEODSS would be participation in a patrol system to find new asteroids.

III. Use of CCDs for GEODSS

CCDs have been investigated for use by GEODSS telescopes. A particular problem for the GEODSS application is the large format required. A front-illuminated array of four CCDs was prototyped by Lincoln Laboratories.[4,5] Compared to the GEODSS SIT tube (with an S-20 photocathode), quantum efficiencies of the CCD were less in the blue region of the spectrum and better in the green and red. The front illuminated CCD responded to the night sky brightness more severely than did the SIT tube due to it's greater red-sensitivity and the attenuation of shorter wavelengths due to the light beam passing through some of the electrode structure. There currently are no plans to install new CCD cameras in the GEODSS system.

References

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