A PROCESS FOR RETRIEVAL OF DATA FROM A COMPILED STAR CATALOGUE

William Stein
Naval Surface Weapons Center
Dahlgren, Virginia

For certain space vehicles there is a need to accurately determine vehicle attitude. Some of these spacecraft, such as NASA's planned LANDSAT-D and Gamma Ray Explorer, will use observations from star sensors to determine fine attitude. One input to the attitude determination software is a specialized stellar data base. The initial step in this software is to identify and match the star images with catalogue stars. The Naval Surface Weapons Center (NSWC) has compiled a special star catalogue for such applications. This paper describes the criteria for the NSWC catalogue and how it is utilized. Because of the large number of stars available, a subset can be divided into cells defined by mission criteria. The cells are stored as a random access mass storage file, thus allowing quick access to the information. This greatly reduces execution time for the software. One scheme for accessing stars from mass storage is described.

The determination of the number of stars and the amount of information for each star should be based on the characteristics of the star sensor and the accuracy needed in vehicle attitude. This leads to the following criteria.

a) Select all stars within a designated apparent visual magnitude (m_v) limit.
b) Gather color information (eg., UBV magnitudes) and spectral classes so that instrumental magnitudes may be computed.
c) Collect accurate star positions (epoch 1950.0) and proper motions along with tabulated uncertainties.
d) Include star identifiers and information on multiple stars, variable stars and parallax, plus other miscellaneous data which may be needed for culling purposes or for instrumental corrections.

This catalogue was originally envisioned to be an extracted subset of SKYMAP (Gottlieb, 1977). We chose SKYMAP because it appeared to be a very complete catalogue having 135 separate pieces of data per star. However to ensure completeness and accuracy of the NSWC subset of SKYMAP, we compared SKYMAP data with that from other catalogues such as

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the CSI and the SAOC. As a result of this comparison, numerous problems with SKYMAP were detected. Thus the simple process of extracting data became quite tedious since, even though the preliminary comparisons were done by computer, many checks had to be done by hand. A preliminary subset of stars was extracted from SKYMAP by applying the four criteria. Many stars lacked spectral class information. So the CSI was examined to see if missing spectral classes could be substituted. During the comparison we detected numerous SKYMAP stars which did not appear in the CSI. Since the CSI is believed to be complete down to $m_v = 9.5$ (Ochsenbein et al., 1977), this was very disconcerting. Our analysis revealed that many of the problems were due to duplicate SKYMAP entries; i.e., a star appearing in both the CD and CPD might have each entry in SKYMAP. Another problem was uncovered when SKYMAP was compared with the SAOC. It was discovered that numerous SKYMAP positions differed from the SAOC positions by more than half a second of arc. This led to a thorough revision of our subset. All SKYMAP stars whose positions did not originate in the SAOC or the AGK3 were eliminated. SAOC and AGK3 positions, proper motions and tabulated uncertainties were substituted for SKYMAP data at epoch 1950.0. In the end, every star in the NSWC subset needed some correction. After all corrections were completed, the catalogue criteria were applied again and the final NSWC Master Catalogue (NMC) of 43,075 stars was produced. The NMC has a star density of approximately one star per square degree, although the distribution is not uniform. We feel confident we have compiled as complete and accurate a catalogue as possible. Any errors detected in the source catalogues have been reported to the authors and to the distributing data centers.

Vehicles such as LANDSAT-D will experience rotation rates defined by an active attitude control system about an axis normal to the orbital plane. If nominal position, velocity and orientation are known, the approximate motion of the star sensor's field of view (FOV) across the celestial sphere can be predicted. In order to determine precise attitude at particular times in the mission, we must be able to rapidly retrieve stars from the catalogue. Yet we do not want to be forced to search the whole NMC every time. Thus based upon specific mission parameters, we can extract a subset of NMC stars and associated data. Such a subset is known as the mission catalogue (MC). To form the MC, we used the following criteria.

a) Eliminate stars violating mission criteria.
b) Only include information necessary for star identification.
c) Store data in a way which is quickly and easily accessible.

The first two steps in forming the MC involve determining which stars to eliminate and what information to retain. This decision is based on such mission-specific factors as instrumental characteristics, vehicle constraints and software restrictions. Once the MC subset is selected, the stars are placed in cells which are treated as elements of a random access file. Software constraints determine the dimensions and number of cells. Globally, there are 1820 cells in our simulations. Those within $\pm 50^{o}$ declination (δ) zone have dimensions of 5^{o} X 5^{o}. For higher δ zones, the right ascension (α) dimension increases until a cap terminates each hemisphere. An indexing scheme allows each cell to be uniquely identified. An algorithm converts the α and δ ranges of each cell to a single integer identifier. Consequently, any star's α and δ can be converted to a cell identifier and its information can be stored in that cell of the random access file. Once a MC has been created for a particular mission, the MC can be used for all observations during the mission unless mission criteria change.

The star identifier software needs a method of quickly accessing a portion of the MC. The vehicle rotation causes the FOV to coarsely trace a swath parallel to the orbital plane across the celestial sphere. The swath length is dependent on the duration of an observation. At specific time increments during observation, the coordinates of the FOV center can be determined and consequently the MC cell containing this point can be identified. Due to uncertainties in the true celestial coordinates of the FOV center, the stars in the FOV cell and in the surrounding cells must be extracted from the MC. These stars can be quickly retrieved from the random access file once the cell identifier is known.

In the next step, the stars are ordered in a sequence more easily manipulated by the software and further eliminations are performed. This is accomplished by transforming the celestial coordinates to a frame having the polar axis perpendicular to the orbital plane. The swath limits including tolerances for pointing uncertainties are easily defined in this frame and any stars exterior to the swath boundaries are eliminated. A large fraction of the extracted stars can be eliminated in this process. Before the remaining stars are sent to the star identifier, their positions can be updated to the instant of observations. If necessary, we only need to apply precession, nutation, aberration, parallax and/or proper motion to a small subset of the MC stars. This access scheme has proven to be quite efficient in simulated missions. Although this paper addresses a specific concept, these techniques could be generalized to solve other aspects of astronomical data retrieval.

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