is an updated implementation of an object-oriented callback system to the Motif widget set.

The benefits of the re-engineered version of GPSS hinge on the object-oriented approach. The use of STL and the improvements in schedule and query operations are incorporated in C++ libraries that may prove useful on succeeding projects. The rewriting of software in C++ increases portability. For the users, every effort was made in the re-engineering to maximize flexibility and improve upon the intuitive nature of the interface without sacrificing any of the capabilities that made the prototype successful.

This work was done by Joseph A. Barretta, Earl P. Johnson, Rocky R. Bierman, Juan Blanco, Kathleen Boaz, Lisa A. Stotz, Michael Clark, George Lebovitz, Kenneth J. Lotti, James M. Moody, Tony K. Nguyen, Kenneth A. Peterson, Susan Sargent, Karma Shaw, Mack D. Stoner, Deborah S. Stowell, Daniel A. Young, and James H. Tulley, Jr., of United Space Alliance for **Kennedy Space Center**. *For further information, contact the Kennedy Commercial Technology Office at 321-867-8130.*
KSC-12043

Bayesian-Augmented Identification of Stars in a Narrow View

An adaptive threshold guides acceptance or rejection of a tentative identification.

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An algorithm for the identification of stars from a charge-coupled-device (CCD) image of a star field has been extended for use with narrower field-of-view images. Previously, the algorithm had been shown to be effective at a field of view of 8°. This work augments the earlier algorithm using Bayesian decision theory. The new algorithm is shown to be capable of effective star identification down to a field of view of 2°. The algorithm was developed for use in estimating the attitude of a spacecraft and could be used on Earth to help in the identification of stars and other celestial objects for astronomical observations.

The present algorithm is one of several that seek matches between (1) imaged star fields and (2) portions of the sky, with angular dimensions equal to those of the imaged star fields, in a catalog of stars in a known reference frame. Previously developed star-identification algorithms are not suitable for fields of view only 2° wide. The present algorithm is based partly on one such prior algorithm, called the "grid algorithm," that has shown promise for identifying stars in fields of view 8° wide. To make it possible to identify stars in fields of view down to 2° with acceptably low probabilities of error, the grid algorithm has been extended by incorporating Bayesian decision theory.

For the special purpose of the grid algorithm, the term "pattern" denotes a grid representation of the relative positions of stars in a field of view. Each star is deemed to be located within one of the cells of a square grid that spans either the field of view of the CCD image or a candidate star-catalog field of the same angular dimensions. The portion of the grid algorithm that generates a pattern comprises the following steps (see figure):

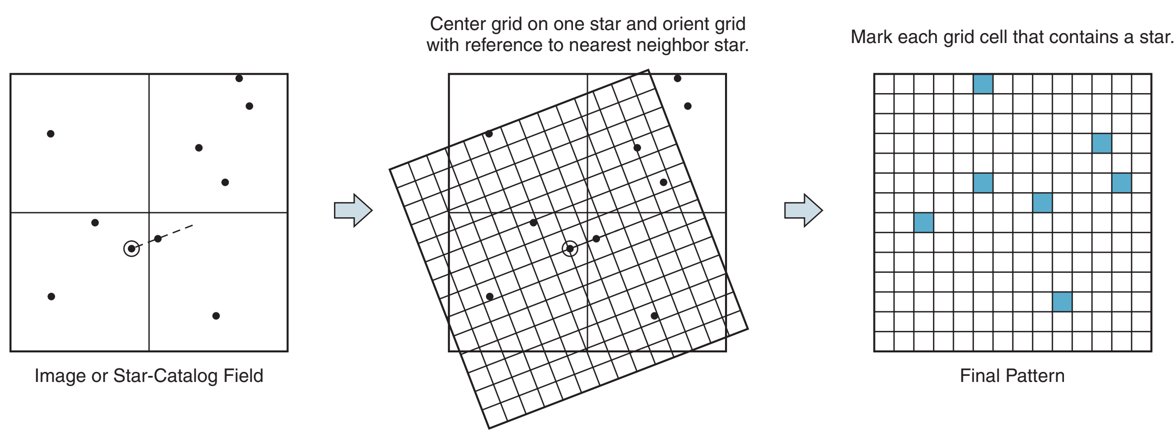
1. Choose a star from the CCD image or the applicable field of view in the star catalog to be the center star.
2. Decide which star is the neighbor star. The neighbor star is deemed to be the star nearest to the center star outside a buffer radius of *br* pixels. The value of *br* is chosen on the basis of experience.
3. Center a grid of *g* rows and *g* columns on the center star, and orient the grid such that a horizontal vector from the center to the right edge passes through the neighbor star. Like *br*, the value of *g* is chosen on the basis of experience.
4. Derive a pattern, a g^2-element bit vector

$$V[0...g^2 - 1]$$

such that if grid cell (i,j) contains a star, then

$$V[jg + i] = 1$$

The vector element corresponding to any grid cell which does not contain a star is given the value 0. The dot product



A **Grid Pattern** is created from either a CCD image of stars or star-catalog data for a field of view of the same angular dimensions as those of the CCD image.

is used to measure how well two patterns V and W match:

$$m = \sum_i V_i W_i.$$

The identification problem then becomes that of finding a catalog pattern that matches the CCD-image pattern. In a typical case, several sources of noise make it impossible to find a perfect match, making it necessary to use a quantitative criterion to decide whether one should accept an imperfect match. One such source is location noise: a star can appear in a grid cell different from that in the catalog. Another such source is magnitude (brightness) noise that affects stars at and near the limit of detectability by the CCD: some stars considered too dim to be included in the catalog could appear in the CCD image, and some stars included in the catalog could be excluded from the CCD image. Still another source of noise is that in the process of producing a pattern centered on a star which is near the edge of the CCD image, some of the grid cells may not be covered by the image. These cells will not contain stars. However, these cells in the corresponding catalog pattern may contain stars.

In the original grid algorithm, the count of stars (m) which match between a CCD image pattern and some catalog pattern is compared against a fixed threshold to determine if the match is good enough to identify the center star. In the augmented algorithm, this fixed threshold has been replaced by an adaptive, probabilistic threshold which takes into account (a) the number of stars in each of the two patterns and (b) the proportion of grid cells in the image pattern lost due to proximity with the edge of the image.

The augmented algorithm has been tested in computer simulations, using a catalog of 934,487 stars brighter than 11th magnitude, along with a variety of different assumed noise conditions. For a $2° \times 2°$ field of view projected onto a CCD of $1,024 \times 1,024$ pixels, a standard deviation of 0.5 pixel in the position of each star as imaged on the CCD, and a brightness deviation of 0.8 stellar magnitude, the algorithm yielded correct identifications in 96 percent of the test examples and false positives in only 0.3 percent of the examples.

This work was done by Daniel Clouse and Curtis Padgett of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1)*
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