Fast Determination of Constellation Membership

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Abstract

The 88 constellations as defined by the IAU segment the sky into regions, separated by an intricate set of boundaries. A binary tree decomposition of this landscape is given which tessellates the celestial sphere into rectangles. This allows a fast determination of the constellation membership of any given sky coordinate.

Key words: constellations – binary tree

Determining the constellation membership of a celestial coordinate is a tedious task: Though the constellation boundaries follow lines of constant declination and right ascension at epoch B1850.0, they take a winding course over the sky to assure consistency with older membership definitions of various sky objects.

A first step beyond the brute-force check of every constellation is a search in a boundary set ordered by declination and right ascension. Roman [2] has prepared such a data table which allows the user to stop the identification process as soon as a positive detection has occurred without processing the remaining constellations. However, the worst case still requires an exhaustive search with a total amount of more than 1,000 coordinate comparisons. This might be prohibitive if a mass classification of celestial objects or an interactive classification in real time is desired.

Several options are available to speed up the search. The most direct approach is to tessellate the sky by a rectilinear mesh such that every mesh cell has a unique constellation membership. While the query of a given cell is O(1), determining the mesh cell from a celestial coordinate introduces some overhead. Furthermore, some 40,000 data entries need to be stored which is far more than the original boundary data.

A more indirect approach followed in this paper is the partitioning of the sky into a binary tree. Trees are known for the efficient structuring of data, though the complicated layout of the constellation boundaries asks for special adaptations. The construction of a binary partition is not unique and allows for the optimization of different goals. A hierarchical division into portions of equal areas minimizes the average search depth, while the worst case performance is not controlled. Splitting the data into sets with an equal number of boundary segments yields a better worst case performance, but is on average inferior to the afore mentioned solution. As the aim of this work is a fast and reliable solution for any location on the sky, the second approach is preferred.

Having fixed the general construction rule of the binary tree, the remaining task is to conduct the subsequent partitioning of the boundary set. The initial boundary data is taken from Davenhall [1] except the additional boundaries for Octans introduced by him. All adjacent collinear boundary edges are merged and edges crossing the 0h meridian are split to assure the reliable detection of candidate splits.
The algorithm used works as follows:

1. Every boundary segment in the current data set is extended to form a candidate split.

2. The current data is divided according to each candidate split while the number of segments in each partition is recorded.

3. The split which minimizes the size of the largest partition is chosen as the final split line. This selection avoids strongly imbalanced trees while avoiding unfavorable cuts at the same time.

4. The boundary segments are divided according to the selected split. Segments on the split line are discarded, segments intersecting the split line are separated into two segments.

5. Each data set is processed recursively until empty. The constellation membership of the corresponding partition is derived from the last split line.

It must be noted that this heuristic can not replace a rigorous minimization of the maximal tree depth, but merely aims at avoiding worst case scenarios. The resulting tree allows the constellation classification with at most 11 decisions, though most queries are resolved with 9 or 10 decisions.

Fig. 1 visualizes the constellation boundaries in B1875.0 coordinates as well as the resulting binary tree. Note how the binary cuts are aligned with the constellation boundaries. Especially Ursa Minor and Octans are victims of the tree balancing criterion. These constellations could be tessellated with a rather small number of cuts, but such splits are discarded to maintain an overall balanced tree. A self-contained C implementation of the constellation search is given as an ancillary file.
Figure 1: Tessellation of the constellation boundaries.
References

[1] A. C. Davenhall. Constellation Boundary Data. http://vizier.cfa.harvard.edu/viz-bin/Cat?VI/49#sRM2.1, 1989.

[2] N.G. Roman. Identification of a constellation from a position. Publications of the Astronomical Society of the Pacific, 99:695–699, 1987.