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5.4.4 Spatial Region Filtering

Another common filtering method selects rows based on whether the spatial position associated with each row is located within a given 2-dimensional region. The syntax for this high-level filter is

```
    regfilter( "regfilename" [ , Xexpr, Yexpr [ , "wcs cols" ] ] )
```

where each "[ ]" demarks optional parameters. The region file name is required and must be enclosed in quotes. The remaining parameters are optional. The region file is an ASCII text file which contains a list of one or more geometric shapes (circle, ellipse, box, etc.) which defines a region on the celestial sphere or an area within a particular 2D image. The region file is typically generated using an image display program such as fv/POW (distribute by the HEASARC), or ds9 (distributed by the Smithsonian Astrophysical Observatory). Users should refer to the documentation provided with these programs for more

details on the syntax used in the region files.

In its simpliest form, (e.g., `regfilter("region.reg")`) the coordinates in the default 'X' and 'Y' columns will be used to determine if each row is inside or outside the area specified in the region file. Alternate position column names, or expressions, may be entered if needed, as in

```
regfilter("region.reg", XPOS, YPOS)
```

Region filtering can be applied most unambiguously if the positions in the region file and in the table to be filtered are both give in terms of absolute celestial coordinate units. In this case the locations and sizes of the geometric shapes in the region file are specified in angular units on the sky (e.g., positions given in R.A. and Dec. and sizes in arcseconds or arcminutes). Similarly, each row of the filtered table will have a celestial coordinate associated with it. This association is usually implemented using a set of so-called 'World Coordinate System' (or WCS) FITS keywords that define the coordinate transformation that must be applied to the values in the 'X' and 'Y' columns to calculate the coordinate.

Alternatively, one can perform spatial filtering using unitless 'pixel' coordinates for the regions and row positions. In this case the user must be careful to ensure that the positions in the 2 files are self-consistent. A typical problem is that the region file may be generated using a binned image, but the unbinned coordinates are given in the event table. The ROSAT events files, for

example, have X and Y pixel coordinates that range from 1 - 15360. These coordinates are typically binned by a factor of 32 to produce a 480x480 pixel image. If one then uses a region file generated from this image (in image pixel units) to filter the ROSAT events file, then the X and Y column values must be converted to corresponding pixel units as in:

```
regfilter("rosat.reg", X/32.+.5, Y/32.+.5)
```

Note that this binning conversion is not necessary if the region file is specified using celestial coordinate units instead of pixel units because CFITSIO is then able to directly compare the celestial coordinate of each row in the table with the celestial coordinates in the region file without having to know anything about how the image may have been binned.

The last "wcs cols" parameter should rarely be needed. If supplied, this string contains the names of the 2 columns (space or comma separated) which have the associated WCS keywords. If not supplied, the filter will scan the X and Y expressions for column names. If only one is found in each expression, those columns will be used, otherwise an error will be returned.

These region shapes are supported (names are case insensitive):

```
    Point        ( X1, Y1 )              <- One pixel square
region
    Line         ( X1, Y1, X2, Y2 )      <- One pixel wide
region
    Polygon      ( X1, Y1, X2, Y2, ... ) <- Rest are
```

```
interiors with
     Rectangle    ( X1, Y1, X2, Y2, A )      | boundaries
considered
     Box          ( Xc, Yc, Wdth, Hght, A )  V within the
region
     Diamond      ( Xc, Yc, Wdth, Hght, A )
     Circle       ( Xc, Yc, R )
     Annulus      ( Xc, Yc, Rin, Rout )
     Ellipse      ( Xc, Yc, Rx, Ry, A )
     Elliptannulus ( Xc, Yc, Rinx, Riny, Routx, Routy,
Ain, Aout )
     Sector       ( Xc, Yc, Amin, Amax )
```

where (Xc,Yc) is the coordinate of the shape's center; (X#,Y#) are the coordinates of the shape's edges; Rxxx are the shapes' various Radii or semimajor/minor axes; and Axxx are the angles of rotation (or bounding angles for Sector) in degrees. For rotated shapes, the rotation angle can be left off, indicating no rotation. Common alternate names for the regions can also be used: rotbox = box; rotrectangle = rectangle; (rot)rhombus = (rot)diamond; and pie = sector. When a shape's name is preceded by a minus sign, '-', the defined region is instead the area *outside* its boundary (ie, the region is inverted). All the shapes within a single region file are OR'd together to create the region, and the order is significant. The overall way of looking at region files is that if the first region is an excluded region then a dummy included region of the whole detector is inserted in the front. Then each region specification as it is

processed overrides any selections inside of that region specified by previous regions. Another way of thinking about this is that if a previous excluded region is completely inside of a subsequent included region the excluded region is ignored.

The positional coordinates may be given either in pixel units, decimal degrees or hh:mm:ss.s, dd:mm:ss.s units. The shape sizes may be given in pixels, degrees, arcminutes, or arcseconds. Look at examples of region file produced by fv/POW or ds9 for further details of the region file format.

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