Notes on Current Method Applied to New Grainy Image

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Contents

1 Introduction

Using a new test image, we see how robust our method is applied to a different (and most likely more realistic) image. The new image measures 1296 x 966 in size, compared to out old image size of 449 x 321. The result is that out image runs slower, but not linearly so.

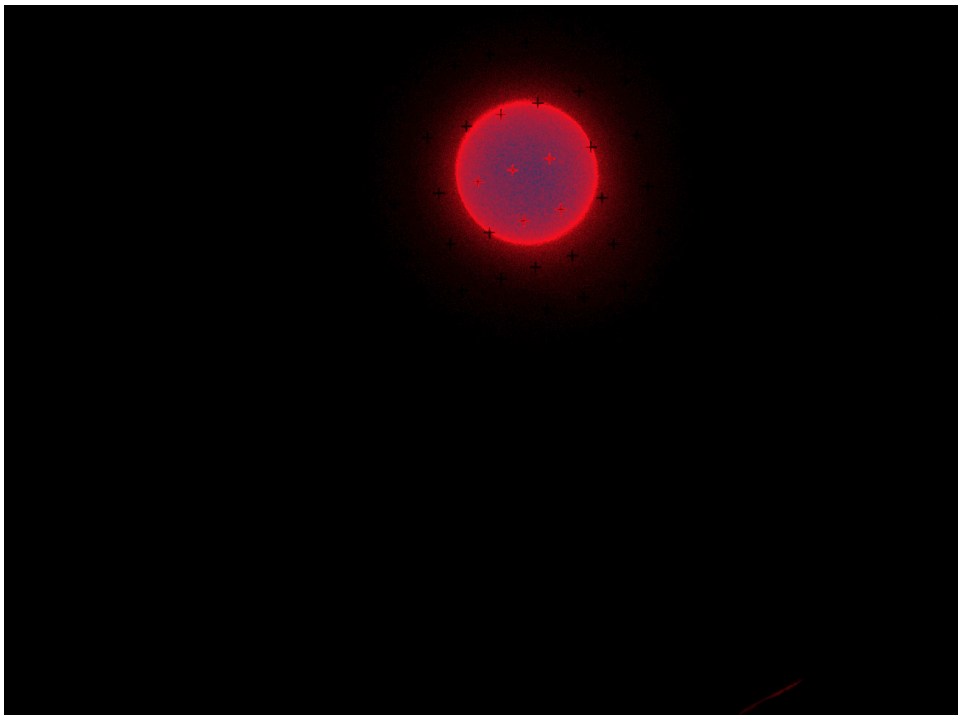


Figure 1: I have used a different color table here (Stern Special) because the black and white image was too dim. The fiducials are staggered and can be seen extending off the solar limbs.

2 How Slow is Slow

Table 1 lays out where our code takes the most time. Part of the process of making the code faster will be looking at which routines are called sparsely but still consume a lot of computing time, like `sort()`, for example.

3 Code Flow Chart

Table 1. Time (Total elapsed: 0.23712516 s)

Routine	Times Called	Time Taken	Time Taken	A Number
SHIFT	14	0.02763	0.02763	1
CONVOL	1	0.02647	0.02647	1
SORT	64	0.02610	0.02610	1
SMOOTH	2	0.01612	0.01612	1
HISTOGRAM	2	0.00705	0.00705	1
LABEL_REGION	2	0.00684	0.00684	1
ERODE	2	0.00428	0.00428	1
TOTAL	141	0.00425	0.00425	1
FLTARR	19	0.00374	0.00374	1
DILATE	2	0.00329	0.00329	1
FLOAT	121	0.00247	0.00247	1
RESOLVE_ROUTINE	1	0.00164	0.00164	1
WHERE	31	0.00159	0.00159	1
CREATE_STRUCT	13	0.00094	0.00094	1
MAX	6	0.00091	0.00091	1
ISA	9	0.00046	0.00046	1
REBIN	2	0.00046	0.00046	1
MESSAGE	1	0.00042	0.00042	1
BYTARR	10	0.00019	0.00019	1
ROTATE	1	0.00010	0.00010	1
READF	12	0.00004	0.00004	1
FIX	21	0.00004	0.00004	1
FINITE	12	0.00003	0.00003	1
STRTRIM	58	0.00003	0.00003	1
SCOPE_VARFETCH	14	0.00003	0.00003	1
ON_ERROR	70	0.00003	0.00003	1
FILE_LINES	1	0.00003	0.00003	1
INDGEN	5	0.00003	0.00003	1
GETTOK	2	0.00002	0.00002	0
STRTOK	12	0.00002	0.00002	1
REPLICATE	8	0.00002	0.00002	1
PROFILER	1	0.00002	0.00002	1
STRMID	34	0.00001	0.00001	1
OPENR	1	0.00001	0.00001	1
DOUBLE	12	0.00001	0.00001	1
DEFSYSV	2	0.00001	0.00001	1
SQRT	63	0.00001	0.00001	1
STRCOMPRESS	14	0.00001	0.00001	1
PTR_NEW	2	0.00001	0.00001	1
PRINT	1	0.00001	0.00001	1
REFORM	33	0.00001	0.00001	1
N_PARAMS	38	0.00001	0.00001	1
ARRAY_EQUAL	5	0.00001	0.00001	1
MIN	7	0.00001	0.00001	1
STRING	14	0.00001	0.00001	1
FREE_LUN	1	0.00001	0.00001	1
STRLEN	36	0.00001	0.00001	1
CATCH	10	0.00001	0.00001	1
ABS	13	0.00000	0.00000	1
SKIP_LUN	1	0.00000	0.00000	1
PRODUCT	5	0.00000	0.00000	1
BYTE	4	0.00000	0.00000	1
SYSTIME	2	0.00000	0.00000	1
MAKE_ARRAY	2	0.00000	0.00000	1
TAG_NAMES	1	0.00000	0.00000	1
PTR_FREE	1	0.00000	0.00000	1
TRANSPOSE	1	0.00000	0.00000	1
FINDGEN	2	0.00000	0.00000	1
STRPOS	3	0.00000	0.00000	1
PTRARR	1	0.00000	0.00000	1
STRUPCASE	1	0.00000	0.00000	1
INTARR	1	0.00000	0.00000	1

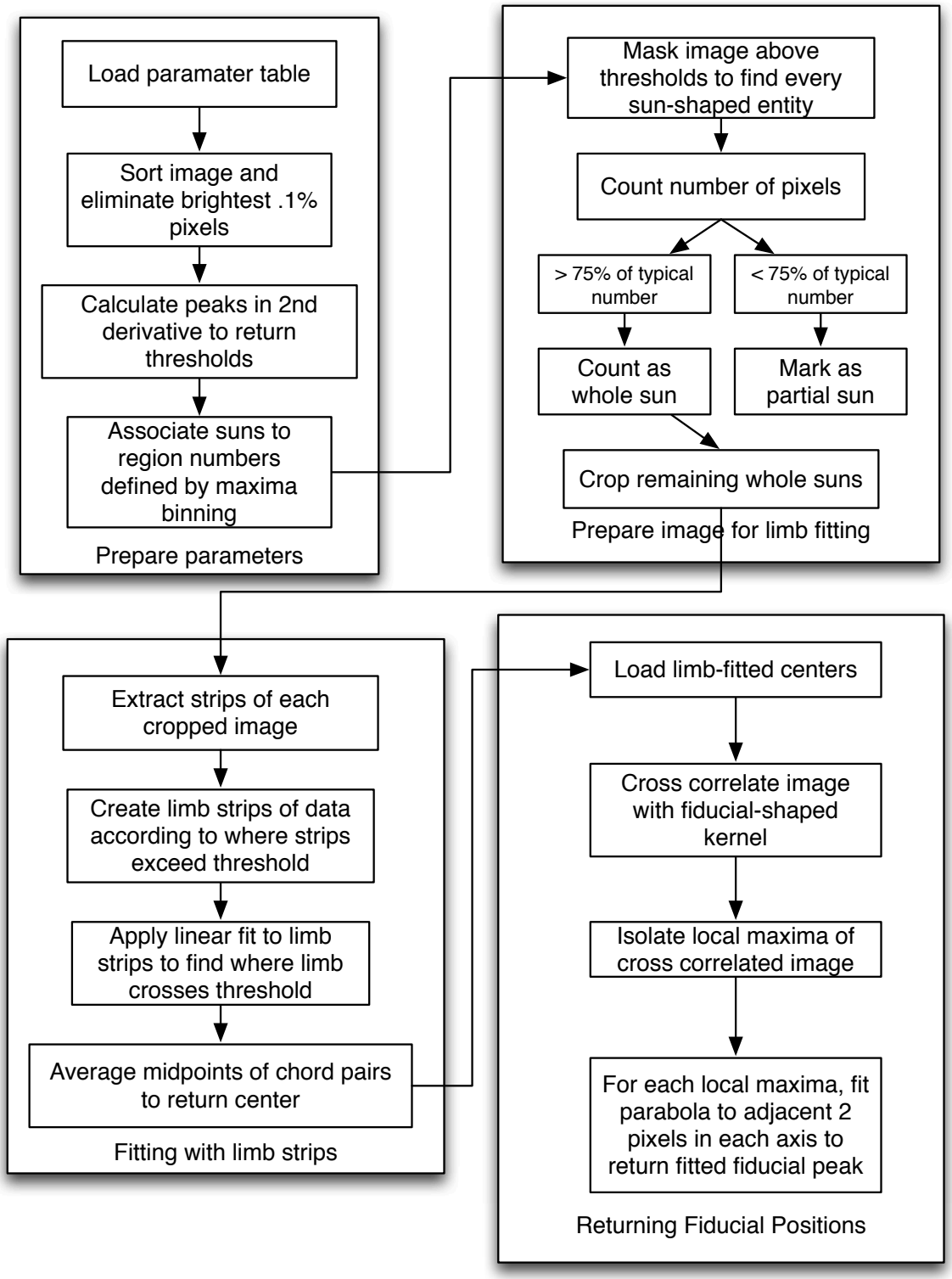

Load paramater table
Sort image and eliminate brightest .1% pixels
Calculate peaks in 2nd derivative to return thresholds
Associate suns to region numbers defined by maxima binning
Prepare parameters
Mask image above thresholds to find every sun-shaped entity
Count number of pixels
> 75% of typical number
< 75% of typical number
Count as whole sun
Mark as partial sun
Crop remaining whole suns
Prepare image for limb fitting
Extract strips of each cropped image
Create limb strips of data according to where strips exceed threshold
Apply linear fit to limb strips to find where limb crosses threshold
Average midpoints of chord pairs to return center
Fitting with limb strips
Load limb-fitted centers
Cross correlate image with fiducial-shaped kernel
Isolate local maxima of cross correlated image
For each local maxima, fit parabola to adjacent 2 pixels in each axis to return fitted fiducial peak
Returning Fiducial Positions

Figure 2

4 The Dreaded Nested For Loop

This is taken straight from Albert's C++ code:

```
for (int m = 1; m < correlation.rows−1; m++)
    {
        for (int n = 1; n < correlation.cols−1; n++)
        {
            thisValue = correlation.at<float>(m,n);
            if(thisValue > threshold)
            {
                //Checks if cross correlated pixel is higher than adjacent pixels
                if((thisValue > correlation.at<float>(m, n + 1)) &
                   (thisValue > correlation.at<float>(m, n − 1)) &
                   (thisValue > correlation.at<float>(m + 1, n)) &
                   (thisValue > correlation.at<float>(m − 1, n)))
                {
                    redundant = false;
                    for (unsigned int k = 0; k < pixelFiducials.size(); k++)
                    {
                        // Checks if previous fiducial correlation values are within 2 fiducial lengths of each other. If so, use the one
                            with a higher correlation value
                        if (abs(pixelFiducials[k].y − m) < fiducialLength∗2 &&
                            abs(pixelFiducials[k].x − n) < fiducialLength∗2)
                        {
                            redundant = true;
                            thatValue = correlation.at<float>((int) pixelFiducials[k].y,(int) pixelFiducials[k].x);
                            Choose the "fiducial" with a higher correlation value
                            if ( thisValue > thatValue)
                            {
                                pixelFiducials[k] = cv::Point2f(n,m);
                            }
                            // Break out of this because there should only be one instance of this per run
                            break;
                        }
                    }
                    // Regardless of whether or not the fiducial was replaced, break out of the loop
                    if (redundant == true)
                        continue;

                    // If we're short a few entries for fiducials, extend the array
                    if ( (int) pixelFiducials.size() < numFiducials)
                    {
                        pixelFiducials.add(n, m);
                    }
                    else
                    {
                        // Dealing with too many fiducials
                        minValue = std::numeric_limits<float>::infinity();;
                        minIndex = −1;
                        for (int k = 0; k < numFiducials; k++)
                        {
                            if (correlation.at<float>((int) pixelFiducials[k].y,(int) pixelFiducials[k].x)
                                < minValue)
                            {
                                minIndex = k;
                                minValue = correlation.at<float>((int) pixelFiducials[k].y,(int) pixelFiducials[k].x);
                            }
                        }
                        if (thisValue > minValue)
                        {
                            pixelFiducials[minIndex] = cv::Point2f(n, m);
                        }
                    }
                }
            }
        }
    }
```

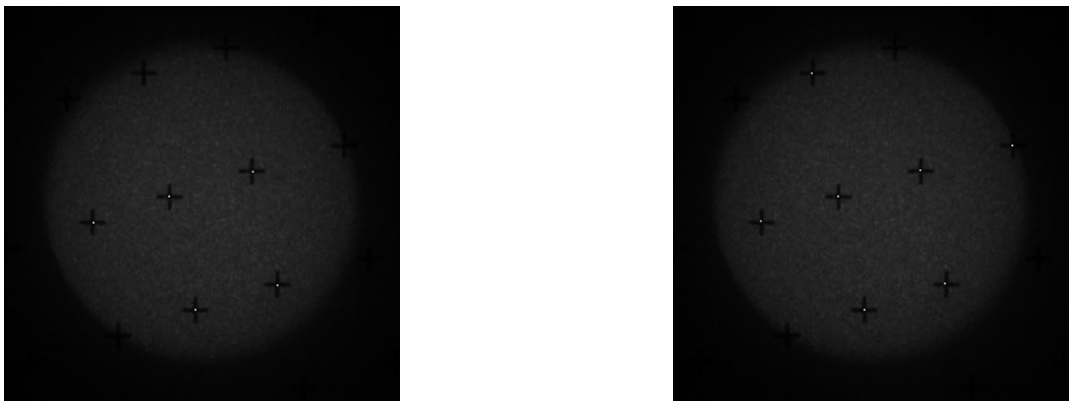
Table 2. Comparison of Fiducial Positions

Fiducial Number	Albert's X	My X	Albert's Y	My Y
0	674.6796	N/A	151.0038	N/A
1	796.3074	N/A	195.0324	N/A
2	740.4443	741.185	210.6342	211.289
3	690.2598	690.985	226.1973	226.961
4	643.4235	644.227	241.8869	242.636
5	755.8672	756.764	279.6622	280.443
6	706.0065	706.809	295.3022	295.957

Table 3. Side Crop Test for Figure 4

Amount Cropped from Limb (pixels)	$x_{\text{True}} - x_{\text{Cropped}}$	$y_{\text{True}} - y_{\text{Cropped}}$
10	-1.17771	-0.0108643
20	-4.07970	-0.0376663
30	-7.63260	-0.0522766
40	-11.7287	-0.0585175
50	-16.2043	-0.0185776
60	-20.9117	-0.0872879
70	-25.7588	-0.277687
80	-30.8586	-0.321724
90	-36.1318	-0.318489

5 Comparison to Albert's Code



(a) The fiducials I find

(b) The fiducials Albert finds

Figure 3: My code can't pick up two fiducials due to one or many of the following factors: different kernel, different convolution method, different threshold.

In Table 2 The fiducial positions are typically within 1 pixel of Albert's calculated positions, which is pretty good.

6 Partial Sun Checking

We're motivated to keep some center data regardless of how cut off a sun may be. To do this, we must quantify the poorness of the fit as more sun is cut off. Figures 6 and 7 aim to quantify the worsening of the evaluated centers. We start by lining up the edge of the image to the solar limb then cropping in 10 columns.

The whole solar image consists of 26,597 pixels above the threshold.

7 Glaring Problems

I was having trouble with proper thresholding but it was alleviated with increasing the smoothing parameter. *Go parameter block!*

Table 4. Corner Crop Test for Figure 5

Amount Cropped from Limb (pixels)	$x_{\text{True}} - x_{\text{Cropped}}$	$y_{\text{True}} - y_{\text{Cropped}}$
10	-1.17902	-1.22132
20	-4.23825	-4.28215
30	-8.41805	-8.49775
40	-13.2540	-13.3160
50	-18.2548	-18.0202
60	-23.0267	-22.9181
70	-27.5755	-27.8987
80	-32.1102	-32.4790
90	-36.6139	-37.0980

Table 5. Side Crop Test for Figure 6

Amount Cropped from Limb (pixels)	$x_{\text{True}} - x_{\text{Cropped}}$	$y_{\text{True}} - y_{\text{Cropped}}$	N_{pixels} above threshold	Percentage of Total Pixels
5	-1.17771	-0.0108643	26250	98.6953
10	-2.52845	-0.0205002	25838	97.1463
15	-4.07970	-0.0376663	25353	95.3228
20	-5.82758	-0.0490799	24795	93.2248
25	-7.63260	-0.0522766	24208	91.0178
30	-9.60011	-0.0380630	23557	88.5701

Table 6. Corner Crop Test for Figure 7

Amount Cropped from Limb (pixels)	$x_{\text{True}} - x_{\text{Cropped}}$	$y_{\text{True}} - y_{\text{Cropped}}$	N_{pixels} above threshold	Percentage of Total Pixels
5	-1.17902	-1.22132	25896	97.3644
10	-2.58559	-2.60790	25079	94.2926
15	-4.23825	-4.28215	24113	90.6606
20	-6.22114	-6.27864	22994	86.4534
25	-8.41805	-8.49775	21805	81.9829
30	-10.8070	-10.8650	20544	77.2418

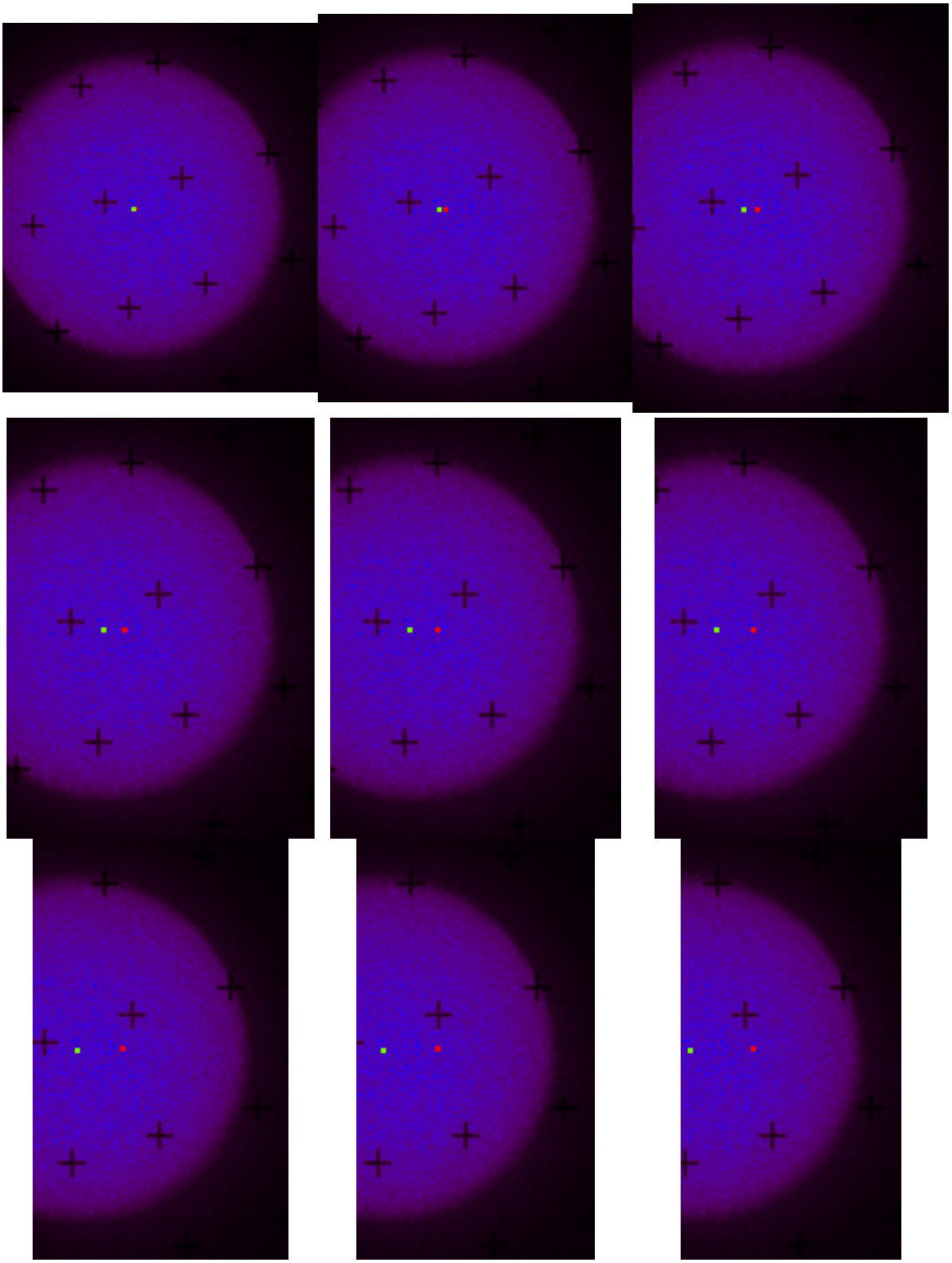


Figure 4: The green pixel is the image's true center and the red pixel is the center of the cropped image. The images are cropped 10 columns at a time.

Our attempts to identify partial suns has evolved from:

1. Determining if center of sun is within certain distance of border
2. Count pixels on very border of image, if 6 consecutive pixels found, mark nearest sun as partial
3. Count number of solar pixels above threshold, if below a certain amount, marked as partial sun

The problem with the second method is that the shape of our mask is designed such that the bottom two corners will always be dark so scanning in a border-pattern will return ill results. We've opted to return to the

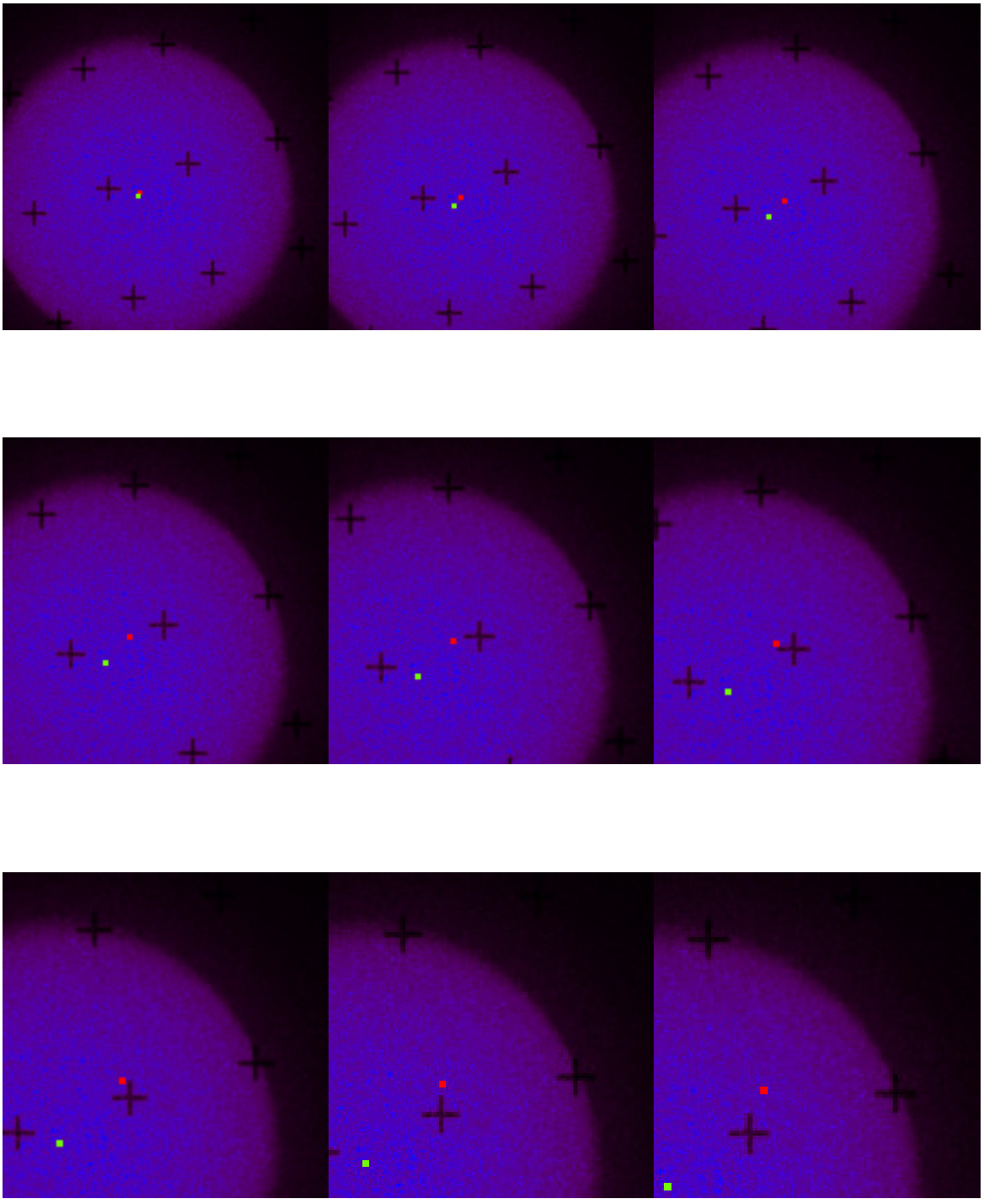


Figure 5: The green pixel is the image's true center and the red pixel is the center of the cropped image. The images are cropped 10 columns at a time.

first method, masking the sun, regardless of shape, and measuring the distance between the mask center and the edge of the image.

A possible approach is to use the mask in Figure 8a and check the distance to the closest non-0 pixel; the problem with this method are the numerous `sqrt()` calls to each pixel on the border of our image.

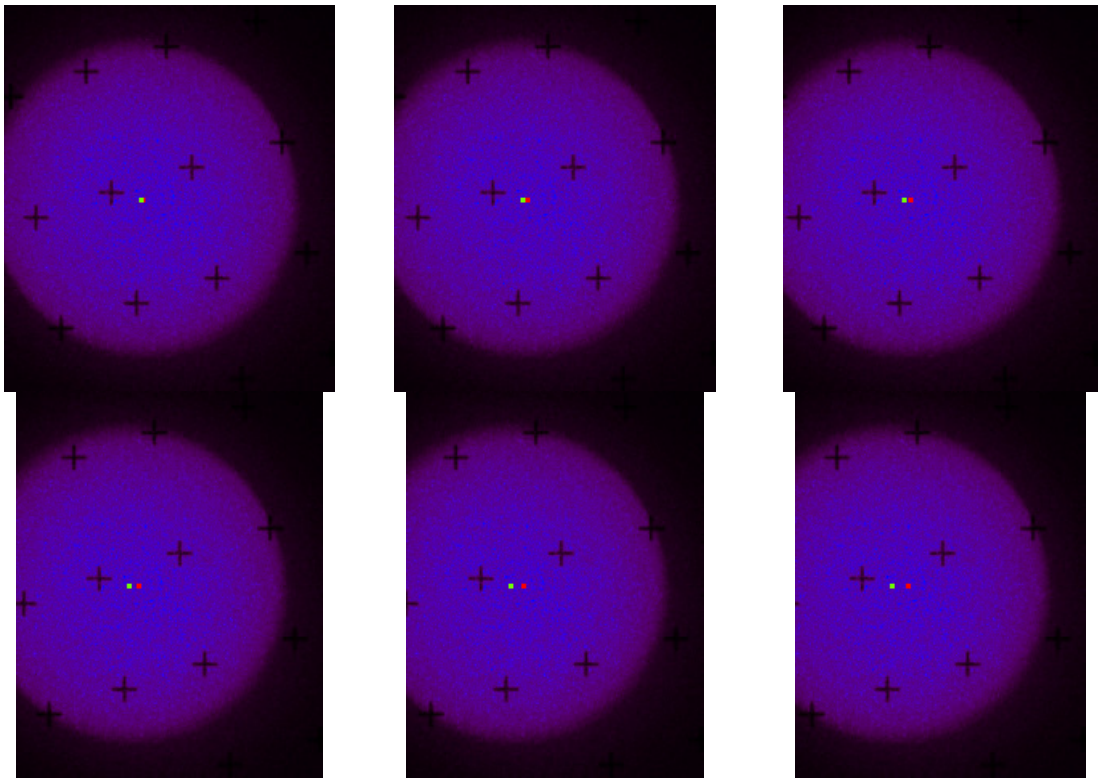


Figure 6: The sun is being cropped off 5 columns at a time, opposed to the earlier Figures' 10.

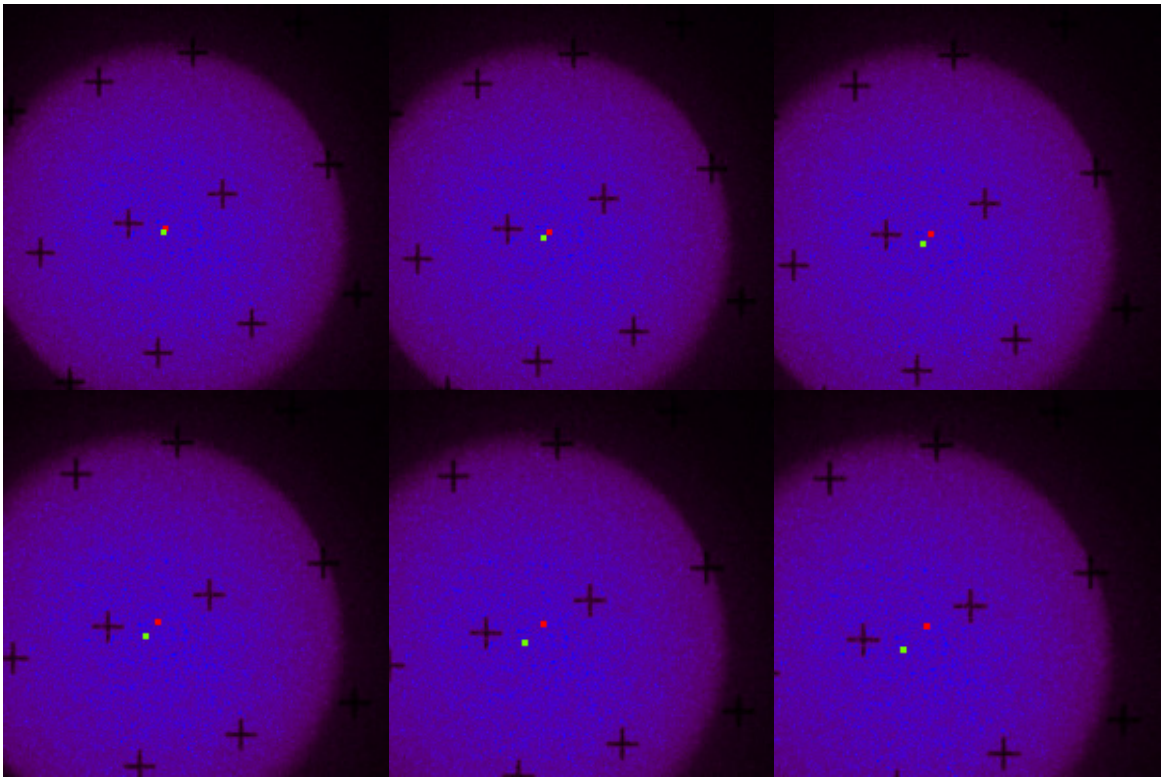
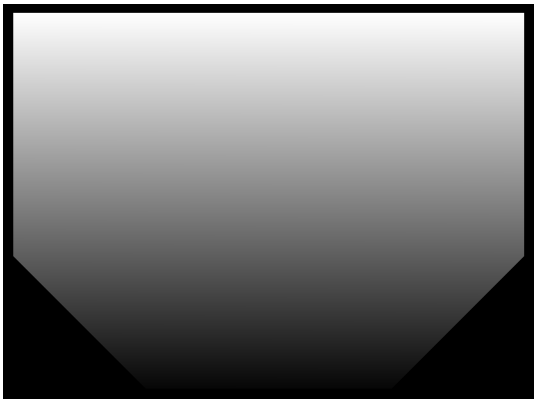


Figure 7

Table 7. Comparison of Center Positions

Method	X Position	Y Position
Mine	710.811	230.695
Albert's	709.7835	230.1023

(a) What our mask should look like - side of black triangle is 1/4 of image width



(b) A proposed mask that looks within a certain distance form the border.

Figure 8: There *used* to be a problem with the mask in 8b; it used an erode function (*which takes an ungodly amount of time*) to shrink the mask used in 8a. Now I pad the image, shift it in all 4 directions, then multiply the masks together.