VBG2000 Ribeye Tolerance Analysis

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03-27-2023

Introduction

Rib eye area contour analysis is one of the, if not the, most complicate part of beef rib eye grading instruments. Especially when muscles are connected to the longissimus dorsi or when fat “cuts” the entire REA. Some of the competitive grading instruments compensate this with manual corrections of the REA segmentation.

It should be known what different line graders are able to reach on up to 400 head per hour.

The biggest challenge is operator placement performance what can easily cause significant variation in REA measurements. That’s the main reason for the developed VBG 7L to flag and improve camera placement over time and the current new development of the VBG robot, a fully automatic solution.

The aim of this document is to investigate the role of the Ribeye area (REA) tolerance given by the USDA draft.

When a certain acceptable tolerance of the REA is given, we want to calculate the amount of change in the Ribeye contour to reach this tolerance. This gives an idea of how accurate the contour detection algorithm and placement should be to achieve such a given REA tolerance.

One could imagen a perfect circle with radius r. Then the area of this circle is $A = \pi r^2$. To maintain a certain tolerance ($\pm\Delta_A\ inch^2$) of the measured area of the circle, it’s easy to determine the maximum and minimum tolerance of the radius $r_{min} = \sqrt{\frac{A-\Delta_A}{\pi}}$ and $r_{max} = \sqrt{\frac{A+\Delta_A}{\pi}}$.

As an example, on a 15-inch² circle a +1inch² tolerance would equal only approx. 0.07inch radius difference. Since the ribeye contour is not a circle and is longer, this tolerance could be smaller.

We propose a tolerance in % since it is a big difference if a fixed tolerance is applied for small or big rib eyes.

Methodology

We erode/dilate the ribeye contour and calculate the REA using VBG2000 until we reach the designated REA limit. Erosion makes the REA smaller, and the dilation makes the REA larger (Figure 1).

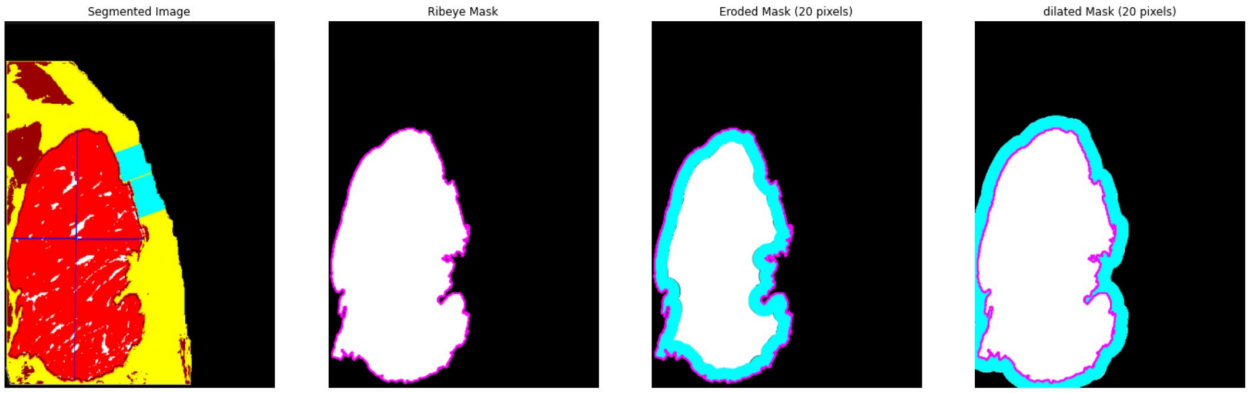

Figure 1 Erosion and dilation of the Ribeye

For example, erosion of the ribeye mask by 1 pixel, means that one pixel is removed from all around the contour, leaving it thinner by 1 pixel from all directions. Dilation works exactly in the opposite way.

The amount of the pixels eroded/dilated is then converted to mm using the image scale of VBG. We interpret this difference in mm to be the equivalent of the change of radius when dealing with perfect circles. There is of course no unique value for this difference since it depends on the size of the ribeye and how uniform/irregular the contour of the ribeye is.

We did this for 20 images of ribeye's ranging in areas from 9 inch^2 to 17.8 inch^2. In Figure 2 there are two examples of these images.

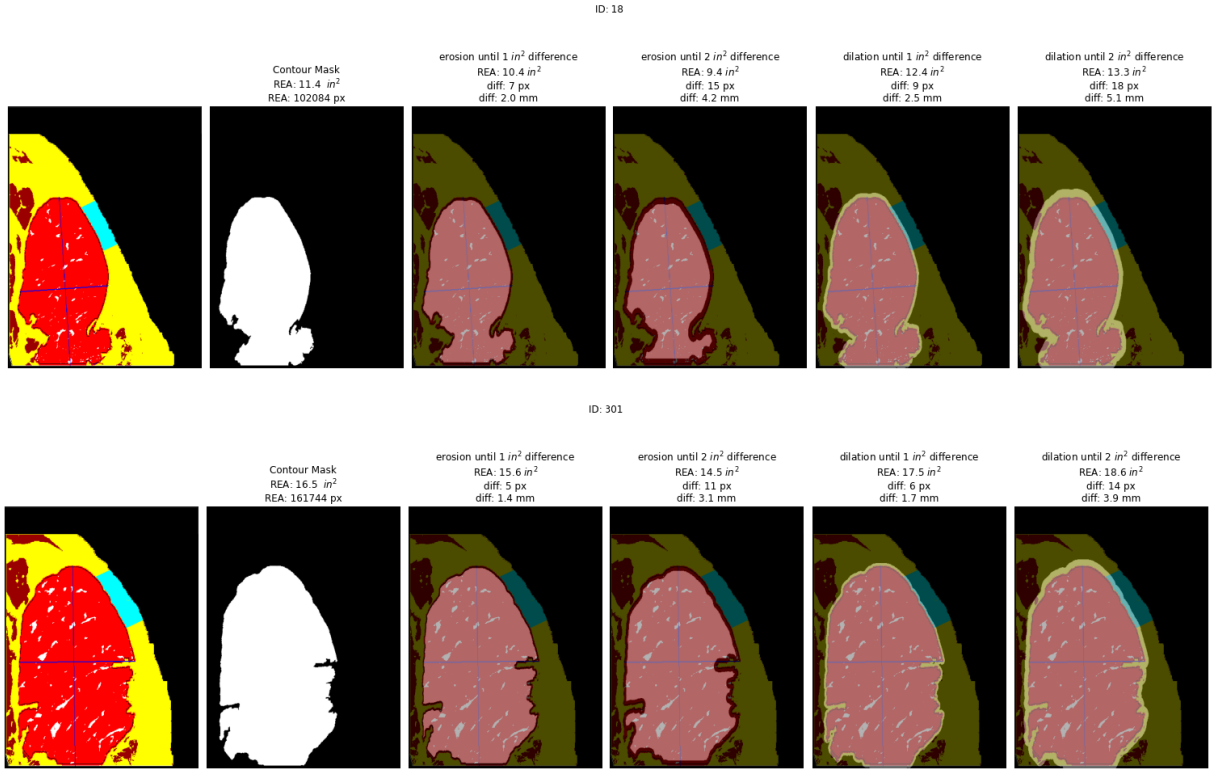

Figure 2 Examples of the used ribeyes

Results

In this section we investigate two REA limits (±1 inch^2 and ±2 inch^2).

The results of all 20 images can be found in Table 1 :

ID	REA (inch^2)	1 inch^2 erode (pixel)	1 inch^2 erode (mm)	2 inch^2 erode (pixel)	2 inch^2 erode (mm)	1 inch^2 dilate (pixel)	1 inch^2 dilate (mm)	2 inch^2 dilate (pixel)	2 inch^2 dilate (mm)
11	11.13	8	2.2	17	4.8	9	2.5	20	5.6
16	11.77	7	2.0	15	4.2	8	2.2	18	5.1
18	11.39	7	2.0	15	4.2	9	2.5	18	5.1
40	12.07	5	1.4	11	3.1	7	2.0	14	3.9
41	17.57	5	1.4	11	3.1	6	1.7	14	3.9
42	15.9	6	1.7	12	3.4	7	2.0	14	3.9
45	14.12	7	2.0	14	3.9	8	2.2	17	4.8
102	12.07	6	1.7	13	3.7	8	2.2	17	4.8
104	12.28	7	2.0	16	4.5	9	2.5	19	5.3
109	9.14	7	2.0	14	3.9	9	2.5	20	5.6
120	15.14	6	1.7	13	3.7	8	2.2	18	5.1
131	11.18	6	1.7	13	3.7	8	2.2	18	5.1
201	9.5	8	2.2	16	4.5	9	2.5	20	5.6
250	10.38	6	1.7	14	3.9	9	2.5	19	5.3
281	9.55	6	1.7	13	3.7	6	1.7	15	4.2
301	16.54	5	1.4	11	3.1	6	1.7	14	3.9
311	17.81	5	1.4	11	3.1	7	2.0	14	3.9
325	14.86	6	1.7	13	3.7	8	2.2	16	4.5
377	13.59	5	1.4	10	2.8	5	1.4	12	3.4
384	14.89	5	1.4	11	3.1	7	2.0	14	3.9

Table 1 Results of the REA Tolerance try.

Table 2 summarizes the observed change in the ribeye mask in mm in all directions, when considering different REA limits.

REA Limit	Min change	Max change	Mean change
-1 inch^2	-1.4 mm	-2.3 mm	-1.7 mm
+1 inch^2	+1.4 mm	+2.5 mm	+2.2 mm
-2 inch^2	-2.8 mm	-4.8 mm	-3.7 mm
+2 inch^2	+3.4 mm	+5.6 mm	+4.7 mm

Table 2 Difference in mm of the ribeye contour corresponding to different REA limits.

Conclusion

Considering the limit (±1 inch^2) we see that it can correspond to min. ±1.4mm or 0,055inch "radius", which is a very small value and it's hard to achieve robustly for most of the analyzed rib eyes and camera operators.

Considering the limit (±2 inch^2) we see that it can correspond to -2.8mm or 0,11inch "radius", which is still a small value given camera operator variations.

Recommendation

We recommend REA measuring tolerances in percentages as follows:

70% of all measured rib eyes within +-10% tolerance

80% of all measured rib eyes within +-13% tolerance

90% of all measured rib eyes within +-16% tolerance

95% of all measured rib eyes within +-18% tolerance