Sherlock 7 Technical Resource

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Industrial Products

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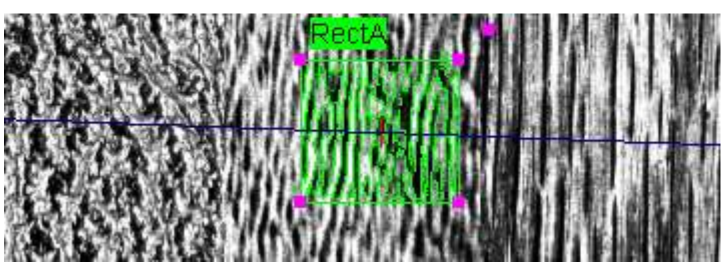
Texture – Edge Angles



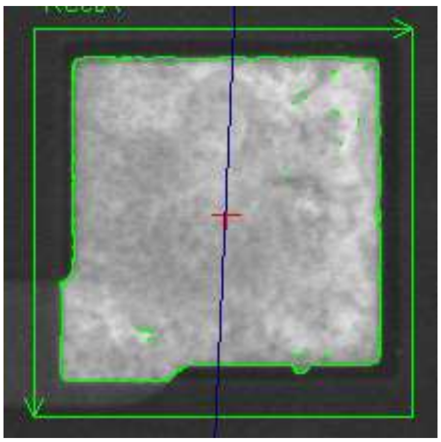
Texture – Edge Angles algorithm measuring texture natural textures (woody fibers), based on the edge density, edge angles (orientation), and randomness (entropy) of edge angles.

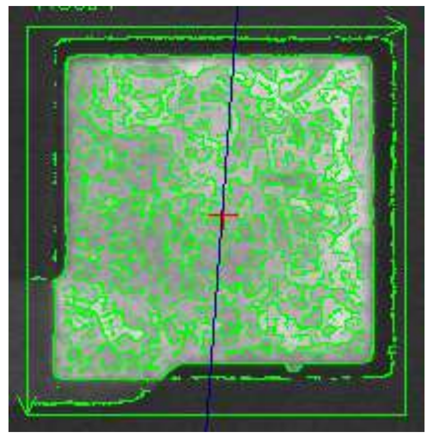
Texture – Edge Angles [algorithm]

Texture – Edge Angles uses edge density, angles (orientations), and distribution to compute texture measures. These measures can be used, for example, to detect different kinds of materials or to monitor the “smoothness” of a manufactured product.

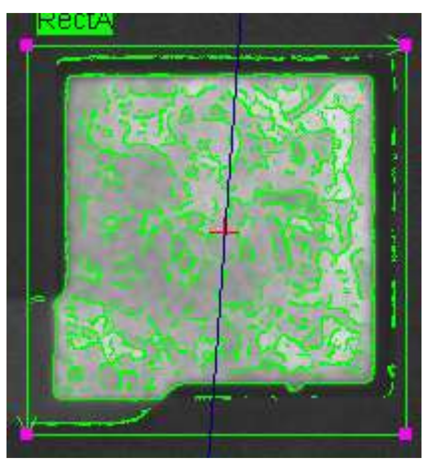
Texture – Edge Angles has two parameters. ***edge detect threshold*** sets the minimum contrast for an edge to be detected. If the view edges used parameter is true, then the edges found are annotated in green on the ROI image.

The left image shows an ***edge detect threshold*** of 16. You can see that small edge variations (in this case, solder ripples) are not detected. Setting ***edge detect threshold*** to 4 (right image) shows some of these ripples, but also picks up some image noise.





Textures, such as the ripple of solder on these bond pads, often have structure at many scales – they are fractals. Using a smoothing or band-pass preprocessor to limit the range of scale of the texture’s structure will often improve the measurement of the texture. For example, adding a Gaussian 5x5 low-pass preprocessor to the previous (right) image reduces the noise and better shows the low-frequency solder ripples:



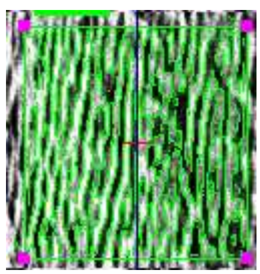
Texture – Edge Angles has eight outputs, but some will not be valid on certain kinds of textures. The outputs are arranged in order of increasing abstraction and order of use.

First we have two measures of the density of edge points in the ROI.

"number of edges" is the number of edge points found in the ROI. If no edge points are found, all numeric outputs are set to 0 and the "edge angle histogram" array is set to zero length. Use this output as a quick test that you have a texture, or to detect when a relatively smooth surface (such as solder) gets disrupted or contaminated.

"% of ROI" is the percent of points in the ROI that are edges. This measure is sometimes easier to use and understand than "number of edges". For example, the solder bond pad shown on the left in the first image has 806 edge points and the image on the right has 7361 edge points. While this is a big difference, a proportion (percent) relative to the total ROI area is easier to work with. In the left image, 2.2% of the ROI's points are edge points and on the right 19.9% are edge points. Note that because edges have a minimum width of 2 pixels, you are unlikely to see a "% of ROI" output greater than 50%.

We now turn to measures that use the distribution of edge angles (orientations) in the ROI. In this algorithm, edge orientations are measured tangent to the edge (the contrast "step"). This is not the usual convention for edge angles, but makes sense when think of a texture as having a "direction". In this image, the dominant orientation of the edges is vertical, so we would say that the edges angles are predominantly 90 degrees (Pi/2):



Angles are measured in degrees in the range of 0 to 180 degrees. Because edges go "both ways" (they are not vectors), only 0 to 180 degrees are needed. For example, an edge at 45 degrees is indistinguishable from one at -135 degrees.

The "edge angle histogram" output is a histogram of edge angles (orientations). This histogram has 18 bins, each 10 degrees wide, so for example, the first histogram bin has a count of the edge points that had an angle between 0 and 10 degrees (nearly horizontal). You can use the histogram as a "pattern" of edge orientations to detect changes in orientation or structure of a texture that has a non-uniform distribution of edge angles.

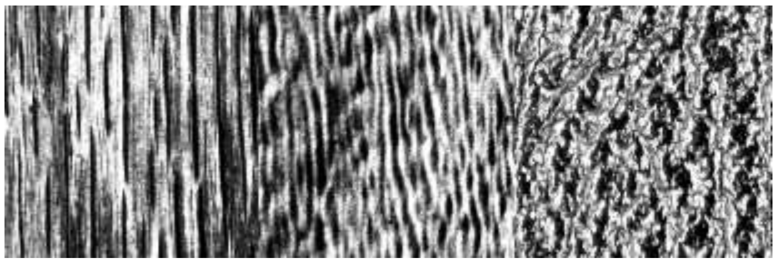
The "major angle" output is the predominant edge angle, in degrees. In the above image, for example, the major angle is 90.7 degrees – nearly vertical.

"% edges at major" is the percent of edges that are within + or – 5 degrees of the "major angle".

Last, we consider the texture measures derived from the edge orientations and positions.

"edge angle entropy" is a measure of the randomness of edge orientations in the ROI. Larger values for this output mean greater randomness of the edge orientations.

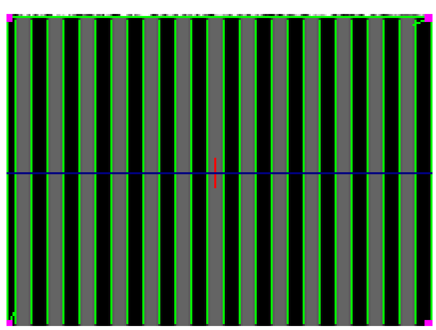
These sample textures have increasing randomness of their edge orientations and so have increasing "edge angle entropy" measures:



1 2 3

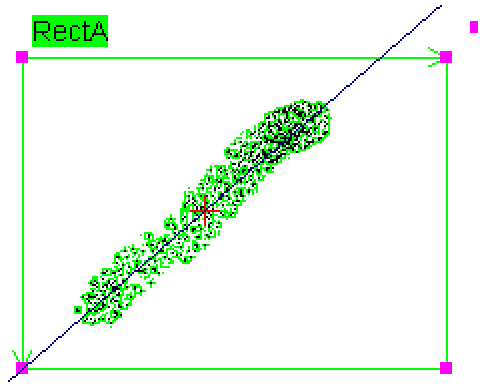
Texture 1 has an "edge angle entropy" output of 2.73, texture 2 has an output of 3.16, and texture 3 gives 4.01.

You can think of the entropy as a measure of the smoothness of the "edge angle histogram". If a texture has edges with orientations at all directions, the histogram will be relatively smooth ("flat") and entropy – the randomness of the edge orientations – will be high. As the texture becomes more ordered towards one edge orientation, entropy (randomness) decreases and the histogram will show an increasingly sharper peak at that edge orientation. This image of uniform vertical bars has only vertical edges and so has an "edge angle entropy" measure of 0:



The "centroid of edges" is the center (center of gravity) of all edge points. This can be used, for example, to detect when the position of a texture has changed on a smooth background.

The "least inertia line" is the axis of least inertia of edge points. This output reading is somewhat difficult to use, as it not immediately obvious what it does! What it does is attempt to fit a line to the positions of the edge points (angles are ignored). In the image below, I created a texture by spray painting a line on a uniform white background.



You see that the "least inertia line" is axis of least inertia – the axis that is easiest to rotate (in 3 dimensions) the set of points about. Think of this set of points as a sausage or hot dog. It is easy to rotate the sausage around its long axis – its axis of least inertia – but harder to rotate it "end over end" because the further points are from the rotation axis (assuming points have uniform mass), the more torque required to move them.

In practice, this measure of texture is only useful in cases similar to the spray paint example – where the texture has an elongated spatial distribution. So, for example, if you have an elongated area of texture, this output reading will tell you the direction of elongation. The centroid tells you the center of the patch and should always be on the "least inertia line".

For textures with fairly uniform distributions of edge points, this output is meaningless. Here, for example, the edge points are distributed over the ROI area and so the axis of least inertia is not defined and the "least inertia line" output is useless.