# Modified Laws Energy Descriptor for Inspection of Ceramic Tiles

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***Abstract:*** *This paper is concerned with the problem of automatic inspection of ceramic tiles using computer vision. The Detection of defects is carried out in three stages: Feature Extraction, Feature Description and Classification. Suitable feature extraction and description improves the performance of inspection system. A number of feature extractors and descriptors are proposed in literature. We selected Laws Texture Energy Measures as feature extractor and descriptor for texture upon ceramic tiles. Then we investigated the suitability of each energy measure of Laws Texture Energy Measures. After experimenting with feature extracted from number of tiles, we define a relationship b/w defect and corresponding suitable energy measures.*

**Introduction**

The quality control is among the major issues in all production industries. Production of ceramic tiles is carried out in number of stages. Final stage of this production requires detailed texture inspection. Traditionally the quality inspection process is carried out by the human. It decreases the reliability as well as the speed of the process. It's also difficult for a worker to glaze at the products and pick the defected ones for a long time. This process affects the performance of the quality control.

The technique discussed in this paper proceeds to the quality control process through the machine vision. Machine vision methods are used to give intelligence to robots that carry out the quality control operation.

**Tile Defects**

In the quality control process of the ceramic tiles the aim is to figure out that the product is good or defective. The quality of ceramic tile is accessed from three different points of view:

1. Aesthetic Quality: Principally surface appearance.
2. Geometrical Quality: Principally the shape of a tile.
3. Technical Quality: A series of technical parameters laid down by the standards must be verified.

But our research work focuses upon aesthetic quality. Basically aesthetic quality is related to visible defects on the surface of ceramic tiles. The variability of the technology used in tile production process makes it necessary for all tiles to be checked for aesthetic quality. Surface defects are concerned with texture analysis. There are mainly three types of defects in the ceramic tiles. i.e.

1. Crack 2. Spot 3. Color

All of above defects are shown in the figures below:


Fig (a) Reference


Fig (b) Crack defect


Fig (c) Spot defect

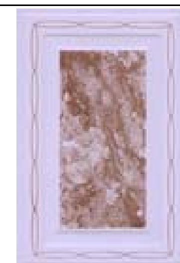
Fig (d) Color defect

**Laws Texture Energy Measure Descriptor for Ceramic Tiles**

Signal-processing-based algorithms use texture filters applied to the image to create filtered images from which texture features are computed.

***The Laws Algorithm:***

**Filter** the input image using texture filters.
**Compute texture energy** by summing the absolute value of filtering results in local neighborhoods around each pixel.
**Combine features** to achieve rotational invariance.

Consider the following convolution masks.

$$\begin{aligned} L5 \ (\text{Level}) &= [\ 1 \ 4 \ 6 \ 4 \ 1\ ] \\ E5 \ (\text{Edge}) &= [\ -1 \ -2 \ 0 \ 2 \ 1\ ] \\ S5 \ (\text{Spot}) &= [\ -1 \ 0 \ 2 \ 0 \ -1\ ] \\ R5 \ (\text{Ripple}) &= [\ 1 \ -4 \ 6 \ -4 \ 1\ ] \end{aligned}$$

L5 (**Gaussian**) gives a center-weighted local average.
E5 (**Gradient**) responds to a row or col step edges.
S5 (**Log**) detects spots.
R5 (**Gabor**) detects ripples.

The 2D convolution masks are obtained by computing outer products of pairs of vectors For example, the mask L5E5 is computed as:

$$\underset{E5}{\begin{bmatrix} -1 \\ -2 \\ 0 \\ 2 \\ 1 \end{bmatrix}} \times \underset{L5}{\begin{bmatrix} 1 & 4 & 6 & 4 & 1 \end{bmatrix}} = \underset{E5L5}{\begin{bmatrix} -1 & -4 & -6 & -4 & -1 \\ -2 & -8 & -12 & -8 & -1 \\ 0 & 0 & 0 & 0 & 0 \\ 2 & 8 & 12 & 8 & 2 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix}}$$

The first step in Laws procedure is to remove effects of illumination by moving a small window (say 15x15) around the image, and subtracting the local average from each pixel. This produces an image whose pixel values are around zero. Next, process the image with the 16 2D convolution filters. Assume $F_k$ (i,j) is the result of filtering with the kth mask at pixel (i,j). The texture energy map $E_k$ for filter k is then

$$E_K(r,c) = \sum_{j=c-7}^{c+7} \sum_{i=r-7}^{r+7} \left| F_K(i,j) \right|$$

Each texture energy map is a full image, representing the application of the kth filter to the input image. Then, combine energy maps of certain symmetric pairs of filters to produce the final nine maps. For instance, E5L5 and L5E5 measure horizontal and vertical edgeness of an image, the average of the two maps indicates total edge content. The final nine maps are

L5E5/E5L5 L5S5/S5L5 L5R5/R5L5 E5E5
E5S5/S5E5 E5R5/R5E5
S5S5 S5R5/R5S5 R5R5

Final result of processing the image is a set of nine images that represent the nine energy maps. In other words, each pixel in the original image is represented as a 9-dimensional vector or energy map components at that pixel. Call this vector E (i,j).

**Relation b/w tile defects and Laws Texture Energy Measures:**

Our basic purpose is to figure out the defects in the ceramic tiles by using texture analysis. For this purpose we calculate the Laws Texture Energy values for each tile. As we see that we see above, for an image we calculate energy values for nine 2D masks, which are shown above. We designed an experiment. Initially texture energy values are computed for the reference tile. Then we picked images of defected tiles, separate images were selected for each type of defect. Then Laws Texture Energy Measures computed for each tile and observed the variation in energy values by certain defect.

This was our basic experimentation setup. The result of our experimentation is described as below.

**Color defect detection:**

In case of color defect, the filter L5E5/E5L5, L5S5/S5L5, L5R5/R5L5, S5S5 and R5R5 showed significant variation, while other filters did not had the significant change. So we considered that others are redundant.

For color defect if the energy values of tested tile for masks L5E5/E5L5 L5S5/S5L5 L5R5/R5L5 are greater than the energy values calculated for the same masks of reference tile, or If the energy values of tested tile for masks S5S5 and R5R5 are less than the energy values calculated for the same masks for reference tile. Then the tile has a **COLOR** defect.

**Crack defect detection:**

In case of crack defect, the filter L5E5/E5L5, L5S5/S5L5, L5R5/R5L5,S5S5 AND R5R5 showed significant variation, while other filters did not had the significant change. So we considered that others are redundant.
For the crack defects there are two conditions. i.e.

1. The energy values of tested tile for masks L5E5/E5L5 L5S5/S5L5 L5R5/R5L5 are less than the energy values calculated for the same masks of reference tile.

2. Now if the difference between the energy values for mask S5S5 of reference and tested tile is less than –0.5000, and if the difference between the energy values for mask R5R5 of reference and tested tile is less than –1.2000. Then the tile has s **CRACK** defect.

**Spot defect detection:**

In case of spot defect, the filter L5E5/E5L5, L5S5/S5L5, L5R5/R5L5,S5S5 AND R5R5showed significant variation, while other filters did not had the significant change. So we considered that others are redundant.
For the spot defects there are also two conditions. i.e.

1. The energy values of tested tile for masks L5E5/E5L5 L5S5/S5L5 L5R5/R5L5 are less than the energy values calculated for the same masks of reference tile.

2. Now if the difference between the energy values for mask S5S5 of reference and tested tile is greater than –0.5000, and if the difference between the energy values for mask R5R5 of reference and tested tile is greater than –1.2000. Then the tile has s **SPOT** defect.

We concluded that for the quality inspection of ceramic tiles only five masks are sufficient. These five masks are as follows:

L5E5/E5/L5 L5S5/S5L5
L5R5/R5L5 S5S5
R5R5

Experimental results for three different type of tiles are shown below:

**TILE NO 1.**

Figure 1

Figure 2

Figure 3

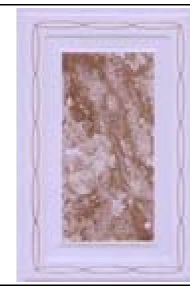

Figure 4

Energy measures and result of those measures are as follow:

| Figure # | L5E5/E5L5 | L5S5/S5L5 | L5R5/R5L5 | S5S5 | R5R5 | Result |
|---|---|---|---|---|---|---|
| 1 | 193.2440 | 128.0504 | 507.3518 | 0.9063 | 4.8020 | Reference |
| 2 | 193.1496 | 127.9926 | 507.002 | 1.0911 | 7.5218 | Crack defect |
| 3 | 190.7198 | 126.3907 | 500.7495 | 0.9474 | 5.5324 | Spot defect |
| 4 | 179.5956 | 119.0063 | 471.5147 | 0.8435 | 4.4744 | Color defect |

**TILE NO 2.**

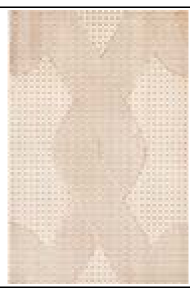

Figure 5

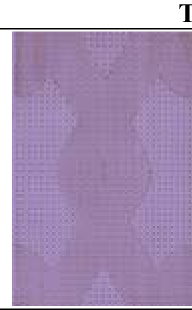

Figure 6

Figure 7

Figure 8

Energy measures and result of those measures are as follow.

| Figure # | L5E5/E5L5 | L5S5/S5L5 | L5R5/R5L5 | S5S5 | R5R5 | Result |
|---|---|---|---|---|---|---|
| 5 | 210.3885 | 140.5110 | 552.6587 | 2.5512 | 22.0488 | Reference |
| 6 | 140.3466 | 93.7257 | 368.5879 | 1.7122 | 14.7655 | Color defect |
| 7 | 209.4153 | 139.8895 | 550.5049 | 2.5746 | 23.0867 | Spot defect |
| 8 | 210.2964 | 140.4590 | 552.4264 | 2.6500 | 23.5811 | Crack defect |

**TILE NO 3.**

Figure 9

Figure 10

Figure 11

Figure 12

Energy measures and result of those measures are as follow.

| Figure # | L5E5/E5L5 | L5S5/S5L5 | L5R5/R5L5 | S5S5 | R5R5 | Result |
|---|---|---|---|---|---|---|
| 9 | 220.1402 | 146.4860 | 584.5676 | 0.2548 | 1.3243 | Reference |
| 10 | 219.6863 | 146.2178 | 583.5990 | 0.2763 | 1.8772 | Spot defect |
| 11 | 227.0782 | 151.1358 | 603.4757 | 0.1989 | 1.0476 | Color defect |
| 12 | 220.1147 | 146.4778 | 584.4706 | 0.5829 | 6.44456 | Crack defect |

## Conclusions

The efficiency of inspection is increased by using computer vision techniques.

Laws texture energy measures are useful tool for the description of texture. Basically nine energy measures are defined. We investigated that five out of nine energy measures are sufficient or useful for description of texture on ceramic tiles. so redundant energy measures from Laws texture energy measures are removed and description process is carried out efficiently. Another benefit of laws texture energy measures, as descriptor is that it simplifies the classifier design.

In future we evaluate the suitability of more descriptors for ceramic tiles texture description and to select powerful and computationally efficient descriptors.

## References


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