Quantitative Analysis of Particles Segregation

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Abstract

Segregation is a popular phenomenon. It has considerable effects on material performance. To the author's knowledge, there is still no automated objective Quantitative indicator for segregation. In order to full fill this task, segregation of particles is analyzed. Edges of the particles are extracted from the digital picture. Then, the whole picture of particles is splintered to small rectangles with the same shape. Statistical index of the edges in each rectangle is calculated. Accordingly, segregation between the indexes corresponding to the rectangles is evaluated. The results show coincident with subjective evaluated results. Further more, it can be implemented as an automated system, which would facilitate the materials quality control mechanism during production process.

Keywords: Quantitative analysis, particles, segregation

1. Introduction

Segregation is a common phenomenon in nature. If it exists in society, it means higher probability of conflicts. If it exists in material, it means defects of materials. In materials, segregation almost always means decreasing of performance. In order to ensure reliable performance of materials, segregation should be evaluated objectively and quantitatively. Then, it can be controlled during material producing process.

However, segregation is analyzed empirically in most research works in most cases currently. To the author's knowledge, there is no automated method available to evaluate segregation objectively and quantitatively. As far as we know, only one objective evaluation index of segregation is available, in which segregation degree is evaluated according to weight difference between upper layer and lower layer[1] of a specimen of concrete. It is a laborious process in practice. However, there is still no automated method available to evaluate segregation objectively and quantitatively. Because segregation has considerable

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influence in many areas, automated objective segregation evaluation method would be a perspective technique to ensure better performance in related areas.

Pattern recognition of digital picture provides a promising way to extract information automatically. It would be a nice method to full fill this task. In this region, different algorithms are proposed to conceal adverse effects of noise[2], to detect majority of variations of images[3] and to detect edges with the influence of light[4]. A neutrosophic edge detection algorithm can remove the noise effect and detect the edges on both the noise-free images and the images with different levels of noises[5]. New approaches improving performance are proposing constantly[6, 7].

Among them, fast edge detection using structured forests is an effective method to obtain edges from digital images. It formulates the problem of predicting local edge masks in a structured learning framework applied to random decision forests[8], the structure present in local image patches is utilized to learn both an accurate and computationally efficient edge detector[9]. The number of contours that are wholly contained in a bounding box is indicative of the likelihood of the box containing an object[10]. The result is an approach that obtains real time performance that is orders of magnitude faster than many competing state-of-the-art approaches[8].

In this work, an automated segregation evaluation method is proposed. At first, photo of the specimen is taken, edges of the particles are extracted from the picture with fast edge detection using structured forests[8, 9, 10]. Then, the picture is splintered into parts with the same size. Segregation index is calculated according to the edges in each part. The experimental results show that the calculated index is correspond with empirically analyzing results. The whole process is easy to implement as an automated one.

The rest of the paper is structured as follows. We discuss segregation and its evaluation method in the next section. In this section, segregation index is proposed and the algorithm to compute it is also given. Experimental results and discussion are given in Section 3. At last, this work is concluded in Section 4.

2. Proposed Strategy

In this work, segregation is computed according to the digital picture of the particles. At first, the picture of the particles is loaded. Then, edges of the particles are extracted with fast edge detection strategy[9]. In order to facilitate the processing speed, the picture is converted to black and white, extracted edges are shrinked. In order to evaluate segregation, the picture is splintered into $rows \times cols$ parts. Average edge length corresponding to each part is computed. At last, segregation between the edge length of the parts is calculated. The detail of the strategy is shown in algorithm1.

In the algorithm1, segregation degree is calculated according to the following equation1, which is constructed according to Gini coefficient[11].

Algorithm 1 Segregation Evaluation Process

```
procedure SEGREGATION(picture, rows, cols)    ▷ The picture to be evaluated, it would be splintered to rows × cols parts with the same size
    pic ← read_picture(picture)    ▷ Load picture
    E ← EdgeDetect(pic)    ▷ Extract edges from pic
    bw ← pic2bw(E)    ▷ Convert to black and white
    respic ← ShrinkEdge(bw)    ▷ Shrink the edges
    SplinteredPicture ← SplitPicture(respic, rows, cols)    ▷ Split it into rows × cols parts
    for i ∈ range(rows) do
        for jinrange(cols) do
            Res[i][j] ← AverageEdgeLength(SplinteredPicture[i][j])
        end for
    end for
    SegregationIndex ← MeasureSegregate(Res)
    return SegregationIndex
end procedure
```

$$SegregateIndex = \frac{n + 1 - 2\frac{\sum\limits_{i=1}^{n}(n+1-i)y_i}{\sum\limits_{i=1}^{n}y_i}}{n-1} \qquad (1)$$

Where:

$SegregateIndex$– Segregate extend of between the parts.
n– Quantity of the parts.
i– The index of the parts.
y_i– Edge length of the ith part.

In equation1, y_i stands for total length of the extracted edges in each part. Segregation degree is calculated according to the difference of the edge length between the parts. If each part has the same edge length, the result will be zero. It means that no segregation exists between the parts.

If the edges of the whole picture are all concentrated in one part, the calculated result will be 1. In this circumstance, segregation of the picture is at its highest point.

In most cases, the extracted edges are distributed among the parts. The calculated value is in $(0, 1)$. The bigger segregation index value means more serious segregation between the parts.

In this way, segregation of the objects in the picture is converted to segregation between the edge length of the parts. Then, segregation degree is evaluated automatically.

This process can be employed in evaluation of segregation between the particles. It is an objective evaluation method. However, this method is also

(a) Sample 1 (b) Sample 2 (c) Sample 3 (d) Sample 4

Figure 1: Distribution of the Mungs

Table 1: Segregation Result of Mungs(Sample 1)

Rows \ Cols	1	2	3	4	5	6	7	8
1	0	1.0000	1.0000	0.9080	0.8500	0.8383	0.8172	0.8005
2	0.8496	0.9499	0.9699	0.9176	0.8999	0.8992	0.8823	0.8787
3	0.6164	0.8466	0.9041	0.8801	0.8595	0.8622	0.8603	0.8533
4	0.6059	0.8311	0.8925	0.8715	0.8599	0.8659	0.8605	0.8577
5	0.5912	0.8183	0.8832	0.8664	0.8537	0.8610	0.8596	0.8538
6	0.5724	0.8056	0.8742	0.8591	0.8497	0.8571	0.8566	0.8537
7	0.5629	0.7983	0.8689	0.8580	0.8474	0.8551	0.8546	0.8508
8	0.5477	0.7889	0.8623	0.8523	0.8433	0.8525	0.8518	0.8496

influenced by the relative size of the particles and the the area covered by the picture. The number of the parts also has some influence on the results. In order to obtain reliable results, the picture should cover enough particles. In this work, the number should be more than 20. On the other hand, if the size of the picture is too big, the edges of the particles would uniformly distributed among the parts. In this circumstance, it would be hard to evaluate segregation. Accordingly, particles covered by this picture are less than three hundred in this work.

3. Experimental Results and Discussion

3.1. Results

Here goes the comparison between these pictures.

According to Table1, the calculated segregation degree is also influenced by the number of rows and columns the picture is splintered into. When the values of the rows and columns are too small, the calculated value varies significantly. When the values of rows and columns are big enough, the calculated value becomes stable. Accordingly, the values of rows and column are set as 7.

The picture of asphalt pavement, which is shown in Figure 4, is taken with SAMSUNG N9002.

Table 2: Segregation Result of Mungs

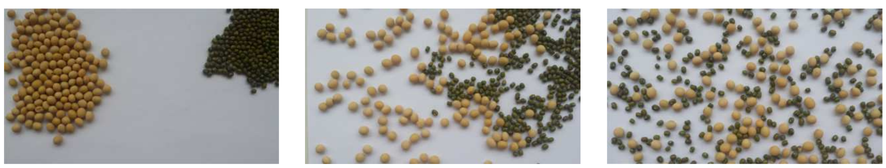
Sample Number	1	2	3	4
Segregation Index	0.8546	0.8009	0.3030	0.2490

(a) Sample 1 (b) Sample 2 (c) Sample 3

Figure 2: Distribution of Soybeans

Table 3: Segregation Result of soybeans

Sample Number	1	2	3
Segregation Index	0.7616	0.3716	0.3054



(a) Sample 1 (b) Sample 2 (c) Sample 3

Figure 3: Distribution of Samples

Table 4: Segregation Result of Samples

Sample Number	1	2	3
Segregation Index	0.6478	0.3933	0.1541

(a) Origin Picture (b) Edge Detect Result (c) Binary Image

Figure 4: Asphalt Pavement

Table 5: Segregation Result of Pavement

Rows \ Cols	1	2	3	4	5	6	7	8
1	0.0000	0.0164	0.0622	0.0438	0.0487	0.0679	0.0723	0.0726
2	0.1908	0.1425	0.1425	0.1358	0.1339	0.1387	0.1407	0.1425
3	0.1682	0.1464	0.1477	0.1542	0.1498	0.1520	0.1548	0.1596
4	0.1665	0.1510	0.1563	0.1685	0.1572	0.1623	0.1682	0.1751
5	0.1630	0.1512	0.1630	0.1718	0.1656	0.1735	0.1751	0.1812
6	0.1595	0.1519	0.1605	0.1691	0.1645	0.1710	0.1753	0.1821
7	0.1538	0.1477	0.1569	0.1710	0.1667	0.1738	0.1781	0.1852
8	0.1519	0.1475	0.1586	0.1704	0.1653	0.1717	0.1783	0.1872

Ginicoeff[11] is used to evaluated segregation quantitatively. The result is 0.1586.

3.2. Discussion

According to the results, the proposed method is an effective approach to evaluate segregation between particals.

The number of parts of the picture splintered should be selected carefully in order to get reasonable results. Unduly high or low value of the parts number leads to unsharpness results. According to the results, the picture is splintered into 6×6 parts is a good choice.

4. Conclusion and Future Works

Segregation has negative influence on material performance. In order to evaluate segregation degree quatitively, digital picture of the particals are taken. Then, edges of the particles are extracted. The result picture is splintered to equal parts, average length of the edges in each parts is calculated. Segregation index is computed according to the edge length of the parts. The results show that the calculated segregation index coincides with intuition.

An ojbective segregation measuring method is proposed, which can be implemented as automated system.

In practice, the parameters such as relative size of the picture and particles should be adjusted in order to get meaningful result.

The proposed segregation quantitive evaluation process is easy to implement as automated program. It would be a promising to ensure material producing process where segregation is important to material performance. This should be conducted in the future.

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