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Particle classification and segmentation of hydrated cementbased on SLIC and multivalued data processing

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ABSTRACT

Cement-based materials are widely used in production and life, but the production process has caused great harm to the environment. Moreover, the existing cement varieties will have various quality problems after several years of wind and sun exposure. Therefore, the study of high-quality cement is of great significance for energy conservation and emission and improving the quality and durability of cement. Many global teams are conducting relevant research, but they try to solve this problem from the perspective of pure materials, which requires a large number of physical and chemical experiments. In this paper, we try to solve this problem in another way. We combine the advanced technology of modern computer science with material and provide a feasible idea and new solution from computer science. We use the cement data obtained by scanning electron microscope to obtain the phase inside the cement through specific analysis means (C3S, C2S, C4AF, C3A, and gypsum). Furthermore, it provides a new method for material scientists to study the influence of internalsubstances of cement on properties.

1. INTRODUCTION

Concrete is the essential component of our urbanized world and the structural basis of modern architecture. Concrete is a synthetic rock made of cement, sand, gravel, and water. It is the most used artificial material so far. Cement accounts for about 10 percent of the quality of concrete and has a vast production capacity worldwide every year. Cement production is not as highly modernized as a traditional industry, and its industrial technology is relatively old. Therefore, it is a major carbon emitter in industrial production. Therefore, it is of great significance to study the relevant properties, proportion, and chemical changes of cement to produce high-quality cement and reduce carbon emission. There are also many teams carrying out relevant work across the world. The effect of cement fineness on the early performance of cement-based materials was studied [1]. Cement particle size distribution was found to play an important role in the performance properties of Portland cement-based materials [2]. Phase, component, and phase transform were also studied in the hydration process [3,4]. The microstructure of the Portland cement was observed in hydration products and helped to broaden the view and mind and overcome the blind spot and defect in the field [5]. Kurdowski explained the relevant chemical principles and knowledge of cement and concrete in detail [6]. Bullard et al. revealed the mechanisms of the cement hydration and made us more clear about the principle [7]. The most landmark research work was the micro-dynamic equation of cement hydration through modeling and simulates the development and evolution of internal microstructure in the process of cement hydration [8]. Carefully monitoring the cement hydration process was proposed and had more advantages than traditional monitoring methods [9]. The influence of finely ground limestone on cement hydration was also studied [10]. There are many outstanding works that cannot be listed here. In this paper, we try to solve this problem from the perspective of the computer. Through the combination of modern computer advanced technology and material science, it provides a new idea and method for material scientists to study cement. We obtained a cement data set through physical experiments. Then, in order to make the dataset more available, we processed the dataset and then used the way of decision tree to distinguish several main phases in cement. Finally, the SLIC image segmentation algorithm is used to segment BSE images according to texture further to verify the inference of phase in the previous step.

The method in this paper draws lessons from Bentz's article [11], but it is also different and innovative from his way, which is mainly reflected in the following aspects. First, the experimental samples are different. Their experimental samples are unhydrated cement, while our samples are hydrated cement of different ages. Secondly, the data processing methods are different. Before using the decision tree, we made a binary (multi) processing on our element distribution map to make the characteristics of cement samples more obvious. Finally, in order to improve the effect of cement phase classification, an interactive image segmentation method is adopted. The image is segmented by SLIC algorithm, which is convenient for experts to distinguish phase in a moreintuitive way.

2. METHODOLOGY AND RESULTS

Firstly, through physical experiments, we obtained a small-scale accurate cement data set, which contains the backscatter diagram of cement at different ages and the distribution diagram of several main elements at the corresponding positions of the backscatter diagram, including calcium, silicon, aluminum, iron, sodium, magnesium, sulfur, and potassium. All cement samples are prepared by ourselves and well preserved, so the reliability of the data is very high.
Because the sampling process of scanning electron microscope has certain randomness, this randomness will turn into certainty only when the scanning time is long enough. But in the actual experiment, a long enough scanning time is not allowed, not only in time but also in money. Therefore, in many experiments, we found an appropriate number of sampling frames to obtain high-quality pictures with low time and money.
However, these data contain noise, so we can't use them directly and need to denoise them. According to the distribution characteristics of different elements, we use different sizes of cores, that is, the size of the filter for median filtering. In this way, we get near noiseless pictures.
Because our cement samples have different ages, cement hydration is a very complex chemical process. With the progress of hydration, various elements will diffuse in the slurry. However, on the surface, the diffusion process is random, but in fact, we can find the statistical law. For example, where C3S exists, there must be many calcium and silicon ions. Therefore, we set different thresholds for different elements to multivalue the element distribution map to better represent this aggregation.

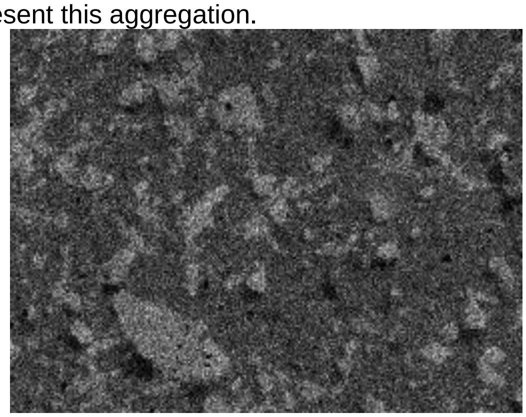

Figure 1. The original distribution map of CA

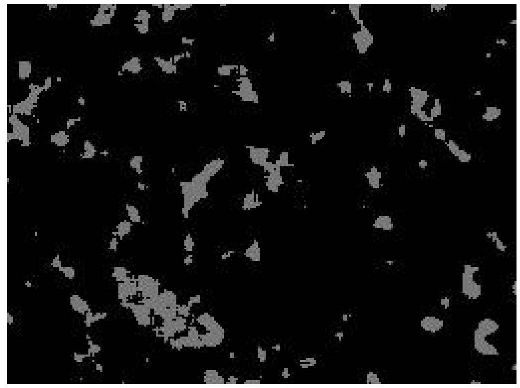

Figure 2. The distribution map of CA after processing

After we get the image after processing, we use the decision tree to decide whether a pixel contains one element. If it has, the corresponding pixels on the BSE image will be marked. Finally, we will determine the phase of the current pixel according to the elements contained in each pixel.

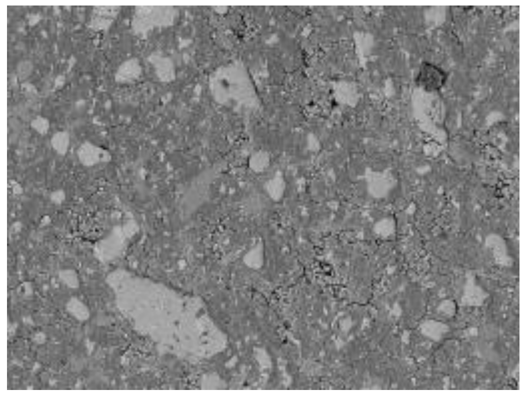

Figure 3. The original BSE image of a block of cement

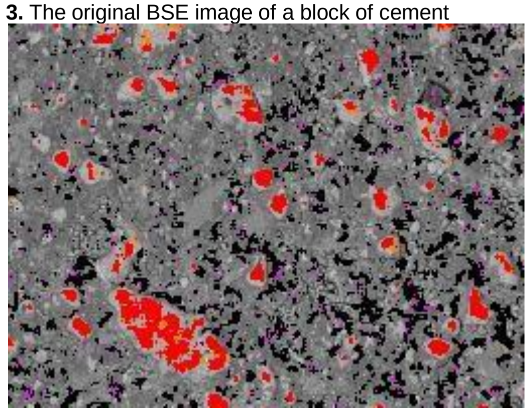

Figure 4. The BSE image which contains the phase

In figure 4, the red represents C3S, the green represents C2S, the orange represents C3A, the blue represents C4AF, the black represents gypsum, the yellow represents Calcium magnesium stone ,the pink represents K2SO4. After this, we use SLIC image segmentation algorithom on the BSE image.

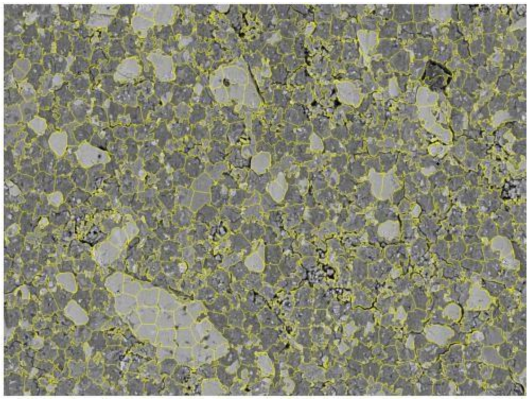

Figure 5. The image after using SLIC

SLIC is a superpixel segmentation technology, which refers to irregular pixel blocks with certain visual significance composed of adjacent pixels with similar texture, color, brightness, and other characteristics. It uses the similarity of features between pixels to group pixels and uses a small number of superpixels instead of a large number of pixels to express picture features.

SLIC is simple linear iterative clustering. The main advantages are summarized as follows: 1) the generated superpixels are as compact and tidy as cells, and the neighborhood features are easy to express. In this way, the pixel-based method can be easily transformed into the superpixel-based method. 2) It can not only segment color images but also be compatible with segmented gray images. 3) Very few parameters need to be set. By default, only the number of pre-segmented superpixels needs to be set. 4) Compared with other superpixel segmentation methods, SLIC is ideal in terms of running speed, compactness of generating superpixel, and contour preservation.

The SLIC algorithm is to segment the image according to the texture of the image. In BSE images, where textures are similar, they often have similar element distribution. Therefore, we use this algorithm to consolidate the inference results of our decision tree so that people can more actively judge the phase distribution on the basis of the decision tree and according to their own experience.

Cement data has strong texture characteristics. Therefore, the SLIC algorithm has achieved good segmentation effect on our data.

3. DISCUSSION

As one of the most important basic materials in the national economy, cement and cement-based materials play an irreplaceable role and position in production activities. They are widely used in many different fields, such as housing, municipal administration, transportation, and so on. The level and scale of China's cement industry have made considerable progress over the years. The output accounts for 60% of the world's total output, ranking first in the world. However, compared with developed countries in cement design tools, the proportion of high-performance cement products is very low, the problem of overcapacity of low-performance cement is serious, and the pressure of energy conservation and emission reduction, especially carbon emission reduction, is huge. After mixing the cement powder with water, it gradually coagulates and hardens from the slurry state with plasticity and fluidity to a solid stone. The hydration process is the dominant phenomenon. However, the hydration process of cement is slow (the standard curing time is 28 days), and it is also vulnerable to moisture deterioration (the grade needs to be reduced for long-term storage), which challenges the rapid and accurate evaluation of cement performance and the rapid design of high-performance products.

Computer modeling and simulation for cement hydration and microstructure evolution have been proven to be a useful tool for understanding the chemical mechanism of cement hydration, predicting the properties of the hydration process, researching the relationship between microstructure and performance, and improving the design of high-performance cement material. However, due to the complexity of cement hydration mechanism and paste microstructure, there’s no fix-positioned hydration model and performance estimation method, which is close to the real development of microstructure from both structure and process.

Scientists failed to establish the relatively real initial status for virtual microstructure, failed to define a development method that reflects the real hydration process of microstructure, and also failed to establish an accurate and logical estimation method for indicators of virtual microstructure.

Here, the method was proposed to solve the main phases features extraction from cement in the physical image. Data analysis and the computer image method were closely combined. The results suggested that this method could deal well with related issues. In this paper, we believe that the following three points are worth discussing and can be explored as future work. 1)For hydrated cement, how to analyze the phase of hydration products is a complex challenge, such as C-S-H gel. 2)The SLIC segmentation result is fused with the backscatter image containing phase into a picture. 3) Explore a method to automatically select the threshold so that the threshold of each element can be selected objectively and accurately to carry out multivalued processing.

1. CONCLUSION

In this paper, from the perspective of modern computer science, we re-examine the problem of

cement phase classification, combine computer science with material science, and achieve good results, which provides a new idea for material scientists to improve cement properties and develop high-performance cement.

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