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Image Processing of Particle Detection for Asbestos Qualitative Analysis Support Method
-Particle Counting by Using Color Variance of Background-

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Abstract: In this paper, we propose the technique classifying background area automatically by calculating the color variance in the RGB space of the picture. By this technique, the background classification robust to change of the background brightness and the background color was enabled. Moreover, we show the effectiveness of this technique by performing particle detection and verifying the result of counting. We aim at development of the particle detector which performs particle counting automatically about the "dispersion staining method" which is one of the processes of asbestos analysis. We used the pictures taken by phase contrast microscopy used for a "dispersion staining method."

Keywords: Asbestos, Image Processing, Particle Detection.

1. INTRODUCTION

In this paper, we propose the particle detection technique for asbestos qualitative-analysis, by image processing. We aim at the automation and increase in efficiency of "dispersion staining method" which are one of the asbestos analysis processes. This technique realizes automating particle counting in a picture taken by phase contrast microscopy.

By this technique, the following processing is performed. First, the picture taken with phase contrast microscopy is divided into small areas. Second, each divided area is classified using the color variance calculated by RGB pixel values of small area. Third, the particles are detected by color information of the classified background area. Fourth, these detected particles are counted. Furthermore, the technique separating particles detected in one particle by mistake is proposed. And particle counting experiment is conducted. The result of this experiment shows the effectiveness of this technique.

The final goal of this research is development of the automatic counting device for "dispersion staining method". We aim at contributing to the large increase in efficiency of asbestos analysis by using this technique.

Fig.1 Traditional Method

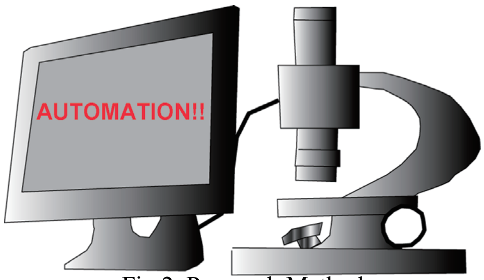

Fig.2 Proposal Method

2. ASBESTOS ANALYSIS

2.1 Necessity of asbestos analysis automation

Recently, asbestos issues are becoming big social problems. Asbestos is group of minerals with long, thin fibrous crystals [1]. There are 6 kinds of asbestos. Such as chrysotile, crocidolite, amosite, tremolite, actinolite, and anthophyllite. The word "asbestos" is derived from a Greek adjective meaning "inextinguishable". The Greeks termed asbestos the "miracle mineral". It is because that asbestos has the many excellent characteristics, such as lightweightness, hypertonicity, soundproofing, insulation, and corrosion resistance [2]. Furthermore, because of its cheapness, asbestos has been used in large quantities after the war. In recent years, if we are exposed by asbestos in large quantities, it became clear to bring great health issues to our body. As main illnesses which asbestos causes, there are a black lung, lung cancer, pleural mesothelioma, peritoneal mesothelioma, etc. Especially pleural mesothelioma and peritoneal mesothelioma are termed malignant mesothelioma. The illness caused by asbestos has very long incubation period. The incubation period of malignant mesothelioma is about 50 years from 20 years. The workers who exposed asbestos in the past have possibilities that they suffer from malignant mesothelioma in the future. It is predicted that the death toll of the malignant mesothelioma in Japan for 40 years will amount to 100,000 people. Many asbestos issues are also seen in Europe. It is predicted that the death toll of the malignant mesothelioma by 2020 in Europe amounts to 500,000 people.

Asbestos has many characteristics mentioned above. Therefore, much asbestos has been used as building materials. 90 percent of import asbestos in Japan is used for building materials. Most of asbestos issues are caused by asbestos in building materials. Now in Japan, if the building has possibility of asbestos containing, the buildings have to conduct asbestos analysis at the time of demolition. This is defined by law. The asbestos import volume in Japan was a peak in the 1970s of rapid economic growth. Buildings built at this time will get older soon. Therefore, it is predicted that demolition of building containing asbestos will increase in the future.

Because of expansion of asbestos damage, and increas e of demolition of building containing asbestos, It is exp ected that the demand of inspection increases rapidly. T herefore, the high-efficiency and automation of asbestos analysis are needed.

2.2 "Dispersion Staining Method" and Its Issues

The process of asbestos analysis is severely defined by the JIS standard (JIS A1481). There are two methods defined as asbestos analysis. One is the "X-ray diffraction method", the other is "dispersion staining method". "X-ray diffraction method" has been already automated. However, many researchers point out that the "X-ray diffraction method" is very difficult. It is because the spectrum is shown very similarly even if different minerals are mixed [3]. Finally inspectors have to determine asbestos identification using "dispersion staining method" as JIS standard. However, automation of the "dispersion staining method" has not realized yet. Therefore, analytical work is performed by inspectors.

"Dispersion staining method" is the technique dyeing only asbestos particles in the sample particles. First, samples are obtained from building materials. Second, the obtained samples are powdered. Third, the powdered samples are dunked by immersion liquid. Finally, observes with a phase contrast microscopy. By changing the polarizing plate, the color of asbestos particles is changed. Then the particles which the color in a phase microscopy picture changed are recognized to be asbestos particles. Change of color is different between asbestos kinds. Therefore, distinction of an asbestos kind can also be performed by "dispersion staining method". At this inspection, if four or more asbestos particles are included in 3000 non-asbestos particles, inspectors judge that the samples contain asbestos. In this work, inspectors have to count all the 3000 particles per one sample using a phase microscopy (Fig.1).

Inspectors are performing this counting work visually now. However, when inspectors count visually, the mar ks cannot be put in the view of a microscope. Therefore, by mistake, particle might be counted repeatedly. Conv ersely, particles might be overlooked. Counting all 3000 particles perfectly is very difficult work, even when the inspectors are experts. Moreover, the work which conti nues looking at a microscope image for a long time need s a large amount of labor, time, and concentration. In the asbestos analysis, "dispersion staining method" is insp ector's biggest burden. Therefore, we think that the incre ase in efficiency and automation of "dispersion staining method" are needed (Fig,2)

2.3 Related Research

Asbestos counting systems have been researched such as Magiscan [4], [5] and AFACS [6]. These researches were aimed at the asbestos crystal which dispersed in the air. In the case of asbestos which dispersed in the air, particles other than asbestos in the samples are very little. However, the target of this research is the asbestos in building materials. Large particles other than asbestos are contained in large quantities. The size and shape of these particles are often similar to asbestos crystals. Therefore, in this research, the counting and recognition of particles are very important.

3. BACKGROUND CLASSIFICATION METHOD

3.1 Necessity of Background Classification Method

In general, for the pretreatment of particle detection, edge detection or background subtraction are used. For the pretreatment of particle detection, edge detection or background subtraction are used.

Edge detection is the technique which investigates change of the pixel value in a picture by differential operator to detect contour. There are primary differential operator and secondary differential operator in the kind of differential operator. However, the picture of "dispersion staining method" in this research has very thin particles and very small particles. Therefore, it is much difficult to detect all particles, such as thin particles, in edge detection.

Background subtraction is a technique which uses the background image taken beforehand. In general microscope image, a background color is constant black. Therefore, once it took a background image, it is applicable to all of the subsequent experiments. However, method which this research used is "dispersion staining method". A "dispersion staining method" observes under a microscope the immersion liquid with which particles and an asbestos particle exist. The brightness and color of immersion liquid changes with reflection of light a lot. Therefore, the background brightness and background color of microscope pictures are changed a lot. If a lot of pictures have to carry out background subtraction, inspectors must prepare large number of background image. Furthermore, background subtraction cannot make effective result, because of its big change of background color. Therefore, background subtraction is very ineffective technique to this research.

Template matching is also used a lot for the particle detection technique. The template image is prepared beforehand. And the area similar to a template is detected from original image. However, because the particles in this research have the various colors, the various forms, and the various sizes, template matching is ineffective technique to this research.

In this research, the particle detection using the feature of particles is difficult. Therefore, we propose next procedure. First, background areas are identified. Second, areas other than a background region are classified with a particle area. Third, classified particle areas are verified. This procedure realizes very effective particle detection.

We aimed at classification of the background area first. The important element for the classification of a background area is to get the effective features. The inspectors can classify a background area and particle area from one picture, and they can count of the particles robust. Even if the color and brightness of a background change. That is because the inspectors do not use neither a color information nor a brightness information, when they detect particles. they can detect particles using other features. The inspectors use the plainness when they view microscope pictures. The simple and plain areas where particles do not exist are recognized to be a background region. And other areas are recognized to be particle areas. Our proposal technique uses this feature. Our technique detects a background area from one picture automatically, and uses as a preprocessing of particle detection.

3.2 Division of a Picture

In this research, the size and color strength of the objective particles are various. If one picture is processed all together, there is possibility that the information of small particles disappears. Therefore, we propose the technique which divides the picture. A picture is divided into small areas beforehand. And small areas are classified to small area where particles exist, other areas are classified to small area where particles don't exist. The picture used by this research is 630x480 (pixel). This picture is divided to small areas (30x30(pixel)). We term the small area where particles exist "particle-small-area", and term the small area where particles do not exist "background-small-area".

The 900 RGB pixel values in each small area are acquired. These 900 pixel values were drawn in the RGB three-dimensional graph. The graph of particle-small-area shows a spreading distribution of the pixel value (Fig.3). On the other hand, background-small-area shows dense distribution (Fig.4). In a background-small-area, the bright pixels of particles do not exist. Therefore this area does not show change of a big color. RGB values are focused to a fixed value. In a particle-small-area, the bright pixels exist. Therefore, the RGB values spread. This feature can always use regardless of the color and brightness of a background. Our proposal technique uses this feature to classify small areas.

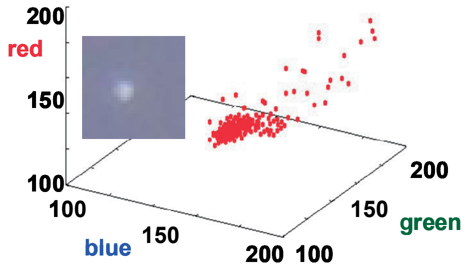

Fig.3 Particle-Small-Area

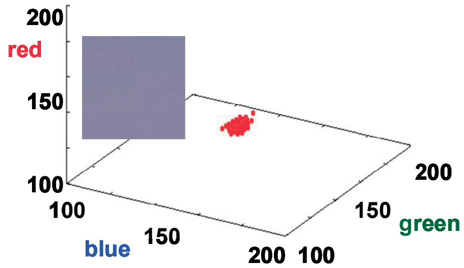

Fig.4 Background-Small-Area

3.3 Qualification of the Feature

The dispersion of pixel distribution in RGB space is quantified by calculation of variance. The variance is the calculation method which measures statistical dispersion, averaging the squared distance of its possible values from the expected value. The calculation method of variance is shown below (1), (2).

$$\bar{x} = \frac{1}{n}\sum_{k=1}^{n} x_k \qquad (1)$$

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{n} (\bar{x} - x_k)^2 \qquad (2)$$

Each RGB variance is calculated by upper formula. Th e variance value of each RGB for every small area is cal culated. The result values are graphed to the RGB three-dimensional graph (Fig.5). From the RGB three-dimensi onal graph, background-small-areas (red circles) show t hat the variance value of each RGB is small. On the oth er hand, particle-small-areas (green squares) show that t he variance value of RGB is large. By the calculation of variance values, we can classify small areas into backgr ound-small-areas and particle-small-areas.

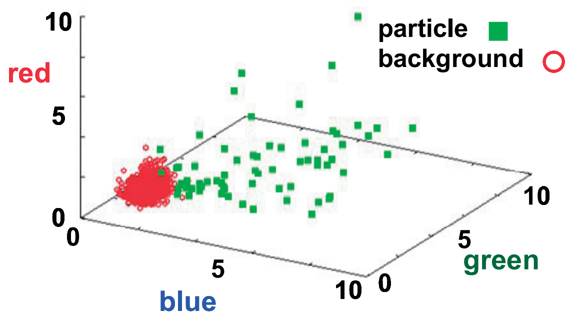

Fig.5 Distribution of RGB Variance

3.4 Application to the Microscope Picture

We apply the "Background Classification Method" technique to microscope pictures by following procedure.

① Prepare the microscope pictures. The size of the pictures is 630x480 pixels (Fig.6 (a)).

② Divide one picture into the small area of 30x30 pixels (Fig.6 (b)).

③ Extract pixel values in each small area and calculate a variance value.

④ Small areas where the variance value is larger than the threshold are classified to a particle-small-area. Small areas where the variance value is smaller than the threshold are classified to a background-small-area.

⑤ Create result picture which painted background-small-areas all black (Fig.6 (c)).

The definition of threshold is the most important factor for classification. At the proposal technique, experientially, the variance value of each RGB defines four or more things as a particle-small-area. On the other hand, the variance value defines four or more things as a particle-small-area. We classify the small areas using this technique in this research.

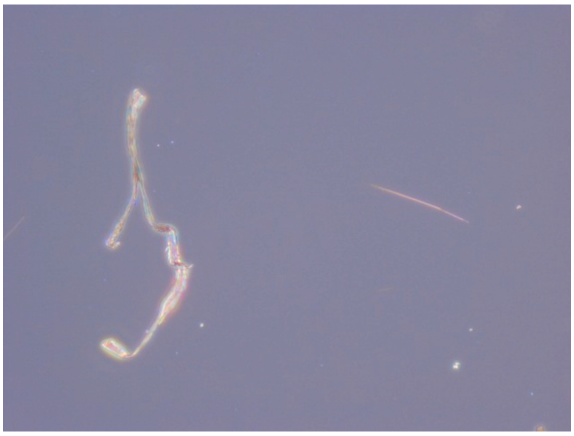

Fig.6 (a) Microscope Picture

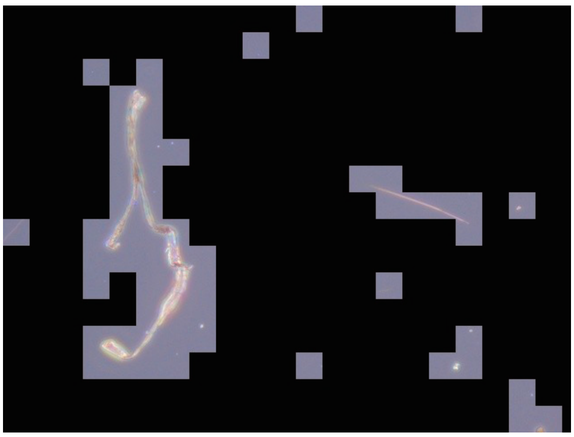

Fig.6(b) Blackout Background Area

Fig.6(c) Make Background

4. PARTICLE DETECTION

4.1 Particle Detection Technique

By above-mentioned technique, we can perform classification of small areas. However, particles can not be counted yet, because detection of particles is not realized. And so, we propose the particle detection technique as the second processing. The most important for particle detection is the high detecting ability of all particles which inspectors can recognize. Threshold has to determine into the value of the background areas very closely. As the proposal technique, if one of the small area's RGB value is larger than the value of the background areas, it is considered as the particle area (Fig.7).

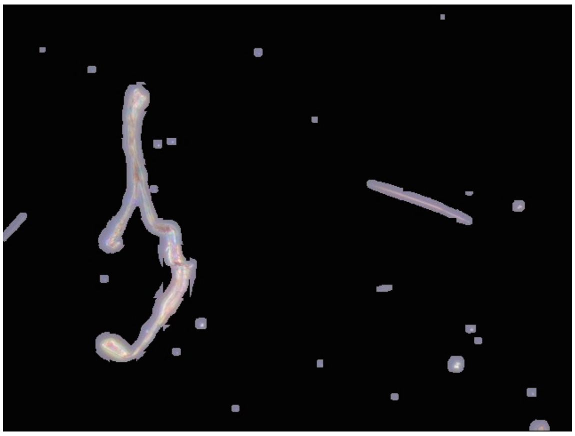

Fig.7 Particle Detection

4.2 Connected Component Labeling

"Connected component labeling" is processing which detects the connected pixels. The number of particles can be counted by counting detected areas. The size of area can be calculated by counting pixels with the same label. The length of circumference can be calculated by counting pixels with the outmost label of the area. Thus, the "connected component labeling" can calculate the number and the feature of particles. When using "connected component labeling", pictures need to be binary images.

There are various ways for "connected component labeling." We used the technique performing by repeating a raster scan. Raster scan is the method which investigates pixels to the right from the left of the picture. And when scanning one line is finished, it scans next line by the same method. Then, it repeats to the end of the picture. At the first scan, if a white pixel is reached, label is attached by the following methods.

1. If the upper pixel is a white pixel, the same label as the upper pixel is attached.
2. If the upper pixel and left pixel are white label, each label is recorded.
3. If the upper pixel is black label and left pixel is a white label, the same label as the left pixel is attached.
4. If the upper pixel and left pixel are black label, the new label is attached.

The label is attached repeatedly by this method.

There are many kinds in "Connected component labeling". 4-connected-labeling and 8-connected-labeling are generally used. 4-connected-labeling detects the pixel connected vertically and horizontally as one area. 8-connected-labeling detects the pixel connected vertically, horizontally, and aslant as one area. When using 4-connected-labeling, one particle is separated to many. Therefore, 8-connected-labeling is used by this proposal technique. Furthermore, if there are very small pixels which cannot be counted by inspectors, these pixels are determined to noise, and it is not counted.

After performing the labeling, the minimum XY-coordinate of each particle area, and the greatest XY-coordinate is found. Using these XY coordinates, the rectangles are drawn in the original picture (Fig.8). Thus, the result is shown visually. And finally, these particles are counted automatically.

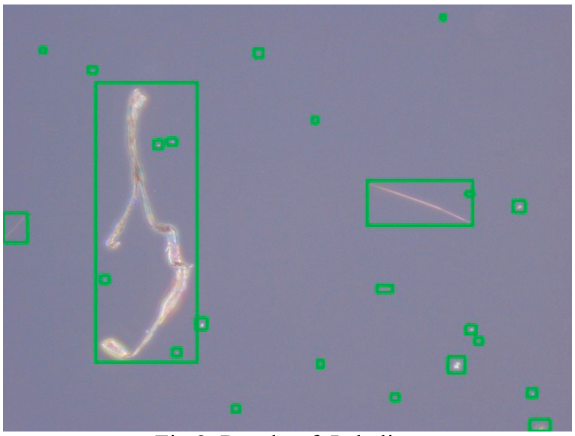

Fig.8 Result of Labeling

5. PARTICLE COUNTING EXPERIMENT

We conducted the particle counting experiment using the proposal technique. The sample used for the experiment was used by actual inspection. And the microscope we used was " Nikon ECIPSE 80i ".

We got the inspector to do counting of the particles in a picture beforehand. Then the inspector's result and the result of the proposal technique were compared and evaluated. Moreover, the experiment using only background difference was also conducted. The pictures used by background difference are pictures picturized under the microscope, before setting samples.

The experimental result is shown below. First, the result of the proposal technique in 15 pictures was compared with the result of the inspector's (Table1). The inspector's counting result was 540. The counting result of the proposal technique was 549. Therefore, the counting rate is 101.7%.

Second, the result of the proposal technique and the result of background difference were compared with the inspector's result. The result of every 15 pictures was shown in the graph (Fig.9). The result of background difference has the large variation in a particle counting rate. On the other hand, by the proposal technique, 12 sheets among 15 sheets were ±10%. Therefore, it turns out that the variation of every picture of the proposal technique is very small. By using the proposal technique, even if the brightness of every picture changed delicately, the highly precise result was realizable. It shows that precise result is depending on the classification of the background area which is preprocessing of particle counting.

Table 1 Particle Counting Result by Inspector and by the Proposal Technique

Inspector	Proposal Technique	Counting Rate(%)
540	549	101.7

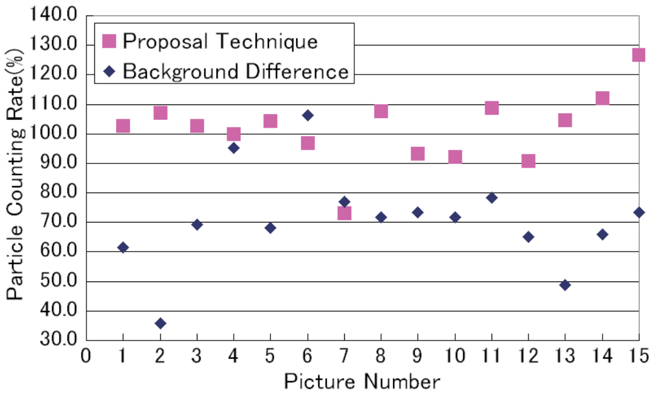

Fig.9 Particle Counting Rate for Every Picture

6. CONCLUSION

We realize development of a particle counting by two processings (the classification of a background area, and particle counting). Moreover, particle counting robust to change of brightness or a color was attained by classifying a background area and creating the model background for every picture as pretreatment. As a result, we could make that variation of counting rate of every picture got small.

ACKNOWLEDGEMENT

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