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Image Processing of Particle Detection for Asbestos Qualitative Analysis Support Method

-Particle Counting System Based on Classification of Background Area-

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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*—component, formatting, style, styling, insert *(key words)

I. 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.

II. Background

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 increase of demolition of building containing asbestos, It is expected that the demand of inspection increases rapidly. Therefore, the high-efficiency and automation of asbestos analysis are needed.

A. "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 marks cannot be put in the view of a microscope. Therefore, by mistake, particle might be counted repeatedly. Conversely, particles might be overlooked. Counting all 3000 particles perfectly is very difficult work, even when the inspectors are experts. Moreover, the work which continues looking at a microscope image for a long time needs a large amount of labor, time, and concentration. In the asbestos analysis, "dispersion staining method" is inspector's biggest burden. Therefore, we think that the increase in efficiency and automation of "dispersion staining method" are needed (Fig,2).

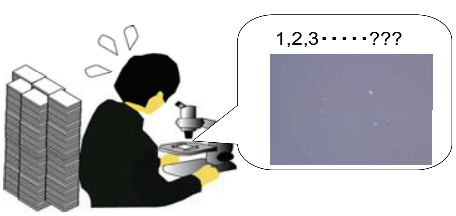


Fig.1 Conventional Method

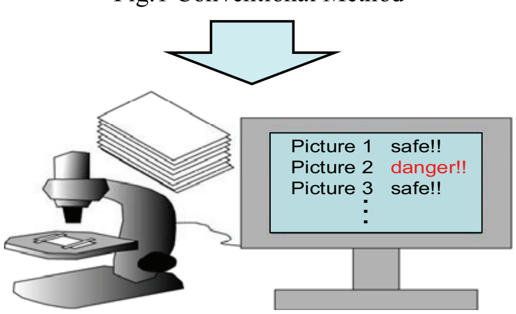


Fig.2 Proposed Method

B. 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.

III. PROPOSED METHOD

A. 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 proposed method uses this feature. Our technique detects a background area from one picture automatically, and uses as a preprocessing of particle detection.

B. 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 exists, 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 proposed method uses this feature to classify small areas.

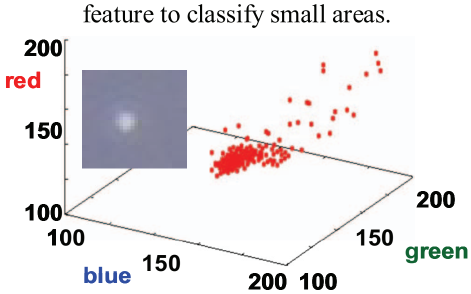


Fig.3 Particle-Small-Area

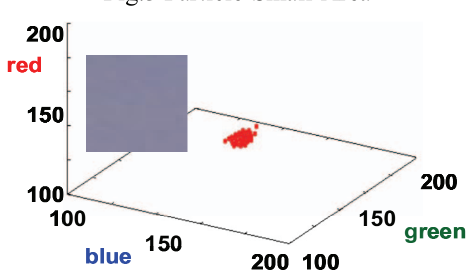


Fig.4 Background-Small-Area

C. Quantification 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).

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

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

Each RGB variance is calculated by upper formula. The variance value of each RGB for every small area is calculated. The result values are graphed to the RGB three-dimensional graph (Fig.5). From the RGB three-dimensional graph, background-small-areas (red circles) show that the variance value of each RGB is small. On the other hand, particle-small-areas (green squares) show that the variance value of RGB is large. By the calculation of variance values, we can classify small areas into background-small-areas and particle-small-areas.

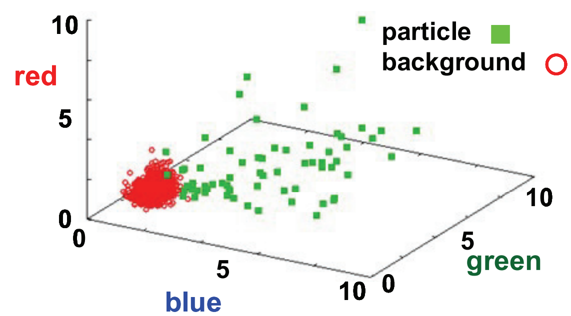


Fig.5 Distribution of RGB Variance

D. Application to the Microscope Picture

We apply the "Background Classification Method" technique to microscope pictures by following procedure. The size of micro scope picture is 379x253 micro meters.

① Prepare the microscope pictures. The pixel 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.

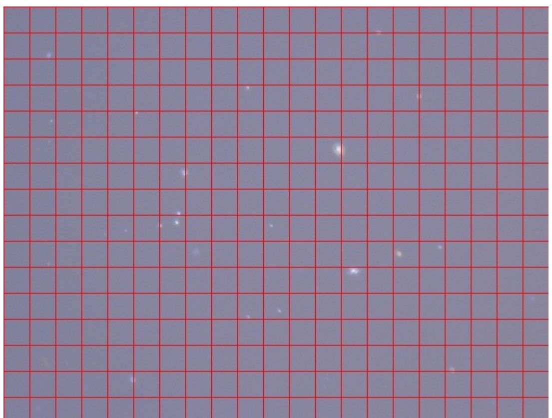
④ Small areas where the variance value is larger than the threshold are classified to a particle-small-area. Small areas where the variance value is smaller than the threshold are classified to a background-small-area.

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

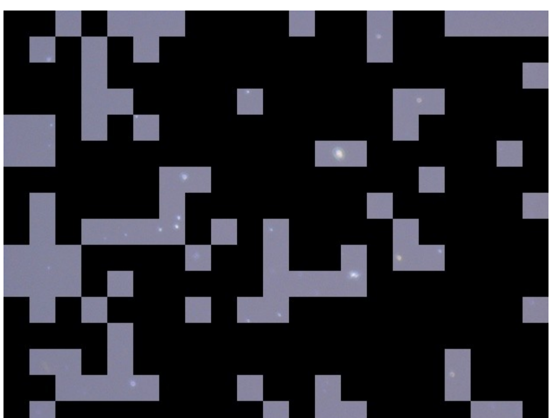
We define the threshold manually in this research. At the proposed method, experientially, the variance value of each

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.

(a) Microscope Picture



(b) Divide the Picture



(c) Blackout Background Area

Fig.6 Background Classification Method

E. Particle Detection

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 proposed method, 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

F. 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 proposed method. 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.

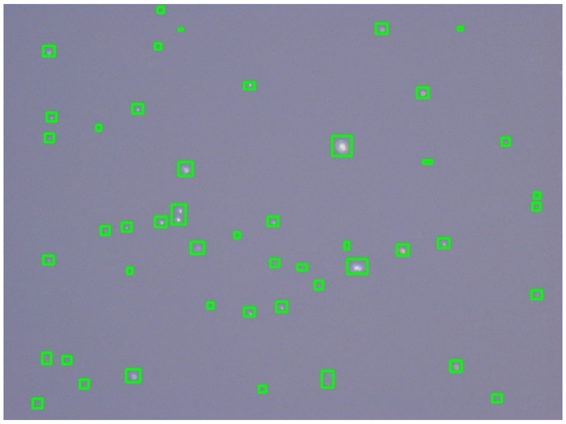


Fig.8 Result of Labeling

G. Re-detection of the Particle Area

When particles existed nearby, particles are detected together (Fig.9). This false detection doesn't make accurate counting result. Therefore, the process of separating these particles is needed. Then, we tried to solve this problem by re-detecting the particle area detected once. The method of re-detection is shown below.

That is because the threshold is defined very severely at 1st particle detection. By defining threshold severely, thin small particles can be detected. However, by this cause, particles are detected together. Especially this false detection is seen, when the number of particles is very large in one picture. This problem can be solved by raising threshold in the area and re-verifying the area. In the case of this processing, re-detecting is very difficult. It is because the detected particle areas are very small. Therefore, the particle areas are re-detected after expanding (Fig.10).

There are many methods to expand pictures. Especially being used commonly is "nearest-neighbor interpolation", "bilinear interpolation", and "bicubic interpolation". "Nearest-neighbor interpolation" is the simple algorithm that the interpolating pixel turns into a nearest pixel value as it is. Although processing speed is very high because of its simple algorithm, there is a demerit that quality of image gets very bad. "Bilinear interpolation" is an extension of linear interpolation. "Bilinear interpolation" does not get quality of image bad like the "nearest-neighbor interpolation". And, the processing speed is high. "Bicubic interpolation" is one of the cubic interpolation techniques. Although the quality of image is high, it often generates fluctuation. Moreover, there is a demerit that processing speed is very low, because of its complex algorithm.

From the above features, "bilinear interpolation" is used for the expansion method of the picture in our proposed method. The result of re-detection is classified to the following three kinds.

I. All particles are disappeared. > one piece

II. The number of particles continues being one piece. > one piece

III. Two or more particles are detected. > The detected number.

The particles detected as the result are shown by the red rectangles (Fig.11).

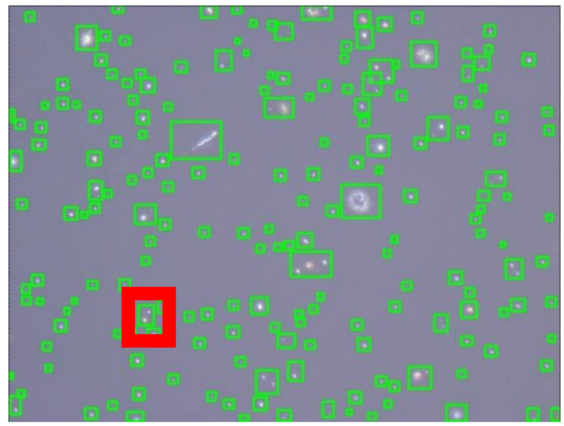


Fig.9 Example of Particles which Detected Together

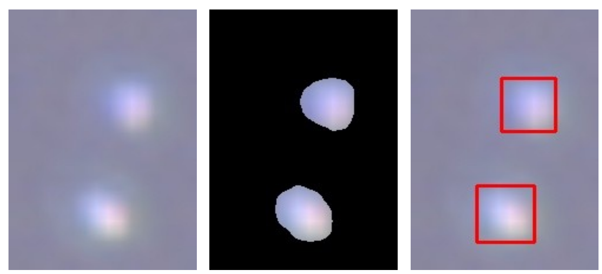


Fig.10 Process of Re-

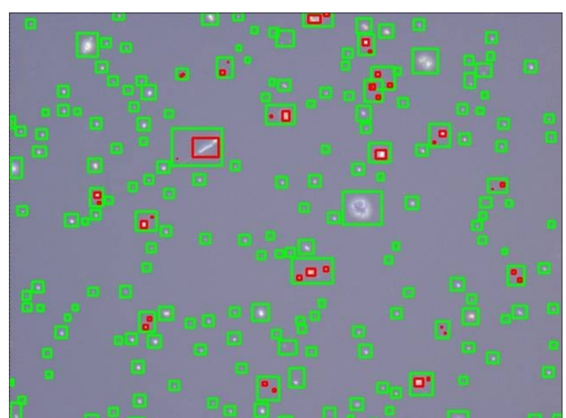


Fig.11 Result of Re-detection

H. Particle Counting Experiment

The particle counting experiment is conducted using our proposed method. The standard sample which actually used by inspectors is used for this experiment. And these samples are taken by a phase distribution microscope "Nikon ECIPSE 80i".

15 pictures are used by this experiment. The particles in 15 pictures are counted beforehand by inspector who is actually conducting asbestos inspection. The inspector's result and the counting result of our proposed method are compared and evaluated. Moreover, the experiment using only background subtraction by the same pictures is also conducted. The background image used by background subtraction is a picture which took only the immersion liquid by the microscope beforehand.

1) Comparision of Counting Result

An inspector's counting result and the result of the proposed method in 15 pictures are compared (Table 1). The number of particles which the inspector counted visually is 540 pieces. On the other hand, the number of particles which this proposed method counted automatically is 549 pieces. When the inspector's counting result is 100%, the detection rate of the proposed method is 101.7%.

2) Evaluation of Re-detection Method

We compare the result of re-detection and non-re-detection (Table 2). The result of non-re-detect method is 27 pieces. On the other hand, the result of re-detect method is 9 pieces. Therefore, 18 false detections caused by too close is solved. this result shows good effect of re-detection method. However, 9 particles cannot solve. This reason is that the some particles are partially-overlapping. These false detected particles need development of another new technique.

3) Evaluation of Classification Background Method

By using 15 pictures, the result of this proposed method is compared with the result of using only background subtraction (Fig. 12). The result of only using background subtraction, the graph shows that the variation of particle counting rate is large. On the other hand, by the proposed method, 12 pictures among 15 pictures attain ±10%. It shows that the variation in the counting rate for each picture is small. Although brightness and color changed delicately with pictures, the highly precise result is realized. This result proves that the robust effect of our "background classification method" which uses at preprocessing of particle detection.

TABLE I. PARTICLE COUNTING RESULT BY INSPECTOR AND THE PROPOSED METHOD

Inspector	Proposed method	Counting Rate (%)
540	549	101.7

TABLE II. COMPARISON BETWEEN NON-RE-DETECTION AND RE-DETECTION

Non-re-detection	Re-detection
27	9

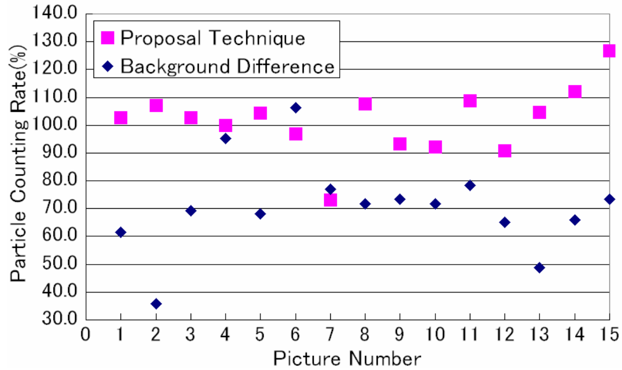


Fig.5 Particle Counting Rate for Every Picture

IV. CONCLUSION

In this research, we propose particle counting method which consists of two processing. First processing is classification of background areas based on color variance. And second processing is particle detection which uses color information of the classified background area. Thus, we realize development of the particle detector. With this proposed method, regardless of changes of brightness and color highly precise particle counting is realized. And by creating a model background for every picture, suppressing the variation in particle counting rate for every picture is realized. Furthermore, by performing re-detection of particle areas, decreasing the number of particles detected together because of its closeness is realized.

ACKNOWLEDGMENT *(HEADING 5)*

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