3D reconstruction and analysis of snow-flakes by using image data

3D Reconstruction and Analysis of Snowflakes by Using Image Data

Kumiko TAKIZAWA[1], Mamoru KUBO[1], Ken-ichiro MURAMOTO[1*]
Nobuhiro NAGUMO[2] and Yasushi FUJIYOSHI[2]

[1] Graduate School of Natural Science and Technology, Kanazawa University
Kakuma, Kanazawa 920-1192 Japan
[2] Institute of Low Temperature Science, Hokkaido University
Kita-19, Nishi-8, Kita-ku, Sapporo 060-0819 Japan
[*]corresponding author: email: muramoto@t.kanazawa-u.ac.jp

Key words: Image Measurement, snowflakes, Voxel, Marching Cubes Algorithm

Abstract

In order to clarify the process of formation of snowflakes and the dependency on weather conditions of snowflakes, it is necessary to measure and analyze the shapes of snowflakes. This paper describes a measuring system for getting two-dimensional image data using three CCD cameras mounted in different locations. In addition, 2D-Video-Distrometer ("2DVD"), the raindrop analyzer, was used for automatic data acquisition. By line scanning, it can obtain data such as drop size distribution, terminal velocity, oblateness, and silhouette image of snowflakes. We present the method for producing the three-dimensional image of snowflakes by image processing.

1. Introduction

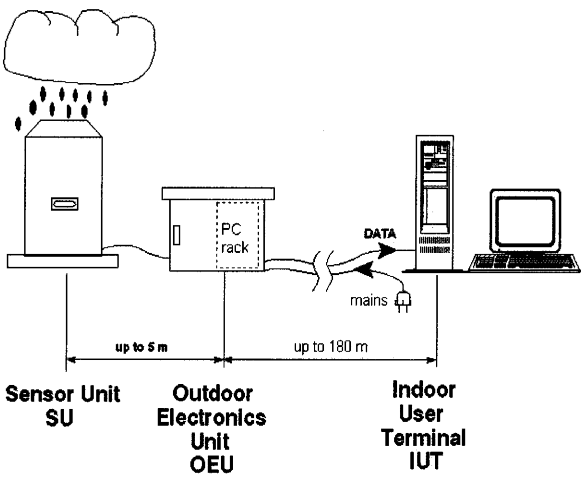
Ice crystals of several tens of micrometers generate in size in clouds and they grow up to become big snow crystals over one millimeter in size. The time it takes to develop is mere ten minutes. Thus, the snow crystals start to fall due to their weight and grow up by attaching to cloud particles [1, 2]. In Japan we can see rimed stellar crystal called dendrite [3]. Because dendrites fall slowly, the number concentration increases and dendrites are more likely to contact each other. In addition, the structure of dendrites which can easily get attach other snow crystals generates the coalescence and makes the snowflakes complicated in shape. Most of the study reported previously presents the measuring system and shape analysis of snowflakes that have fell to the ground.

However, these methods deal only with "crushed" snowflakes, so the results are not necessarily corresponding to the data obtained by measuring falling snowflakes. In this study, 2DVD is used for 3D shape analysis of snowflakes during fall. 2DVD is a raindrop observational equipment with two line scan cameras, which makes it possible to obtain data such as shapes of snowflakes, terminal velocity, drop size distribution, and so on. Moreover, we can conduct the real-time observation stably and handily by using accompanying software. 2DVD is used for the acquisition of binary image (silhouette image) as shapes data. Image histogram and 3D data are also required for detailed analysis. However, this data is not enough to analyze the shapes of snowflakes. Therefore, in this paper, we present two methods for capturing images of snowflakes - using 2DVD and video cameras, and a 3D image processing technique that utilizes the advantages of both methods.

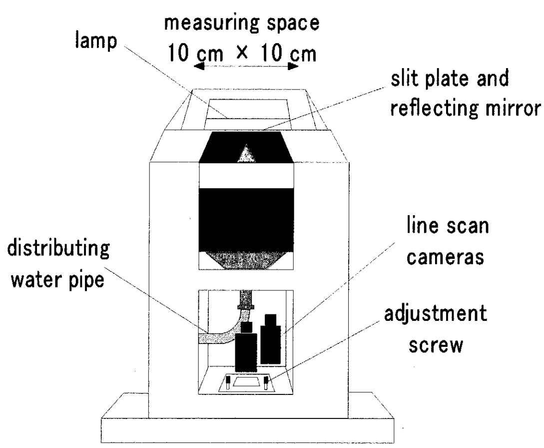
2. Observation Equipment

2.1 2D-Video-Distrometer

By line scanning, 2DVD provides various data - drop size distribution, terminal velocity, oblateness, rainrate, and binary images as shapes from two directions in real time.



a) Three components of 2DVD.



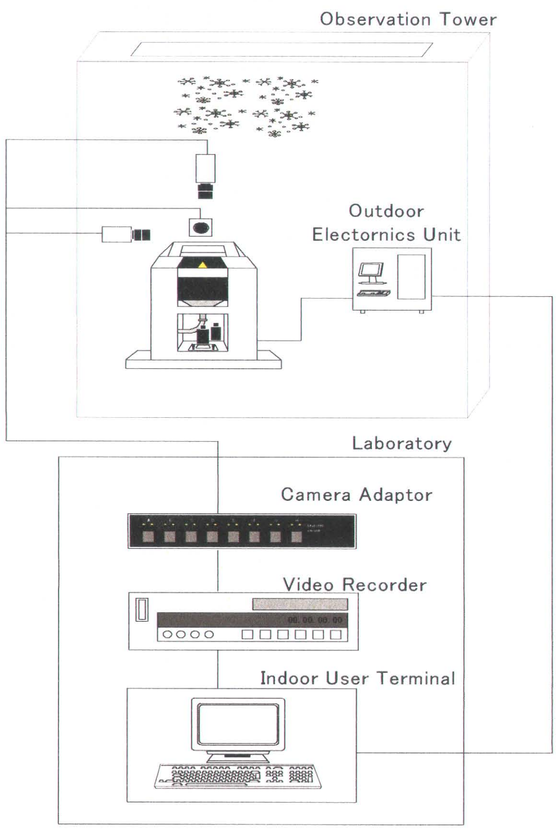
b) Sensor Unit.

Fig.1 Outline drawing of 2D-Video-Distrometer.

This system consists of three components; A sensor unit that observes the falling particles in a measuring area by line scan cameras, an outdoor electronics unit that carries out data processing and transfer, and an indoor user terminal that can be used to analyze the data with software (Fig.1a). The sensor unit acquires images of snowflake shapes by sensing the shaded light source. The line scan speed is 29 μs per line. The measuring area (width: 10 cm, height: 6 mm) is illuminated with a slit plate and reflecting mirrors. Fig.1b shows an outline drawing of sensor unit.

2.2 Measurement system using video cameras

Fig.2. shows the construction of measuring system for taking grayscale images. Two halogen lamps illuminate a space which is 5 cm above the measuring area (10 cm×10 cm). Three CCD cameras are mounted in three locations (640×480pixels, grayscale). The shutter speeds of the cameras are set at 1/4000 s (north and east side) and 1/1000 s (upper side), and the data is recorded by video recorder. The spatial resolution is 0.12 mm/pixel.



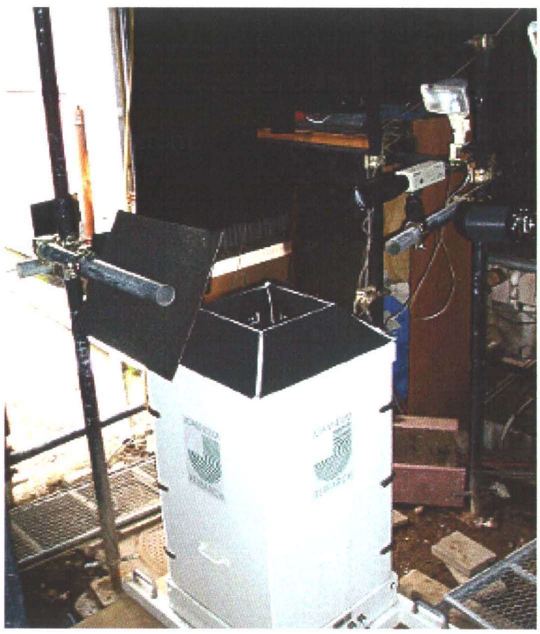


Fig.2 Measuring system.

3. 3D Reconstruction Method

3.1 Volume intersection

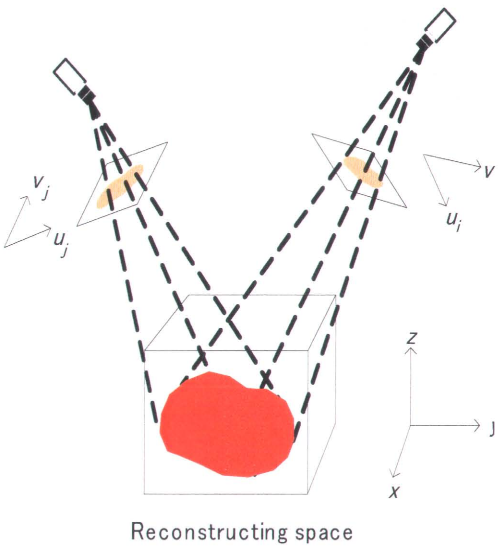
Volume intersection is an image processing method that generates virtual 3D space and reconstructs a 2D silhouette captured from multi cameras by backprojection and "AND" operation [4, 5] (Fig.3a). In this study, the shapes of snowflakes are too complicated for us to get meticulous reconstructions. Therefore, this method is adopted to achieve approximate reconstruction. In order to convert three grayscale images into the silhouette images, image binarization and median filtering are used.

3.2 Creation of the volume data

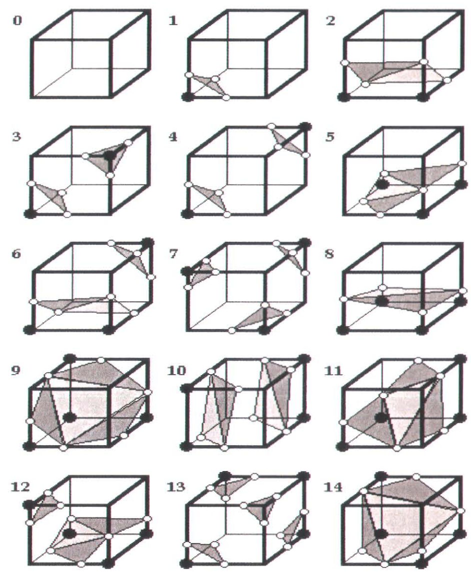
The three preprocessed images are aggregated into "voxel" data by the backprojection method using the volume intersection in virtual 3D space. Each voxel value V is given by the following equation,

$$V(x,y,z)=\frac{1}{N}\sum_{n=1}^{N}P_n(u_n,v_n) \qquad (1)$$

where P is the grayscale value of a image, N is the number of images, x, y and z are the coordinate values in a virtual space projected by u_n, v_n in a 2D plane.



a) Volume intersection.



b) Patterns of polygons generated Marhching Cubes Algorithm.

Fig.3 3D reconstruction method.

3.3 Rendering

To visualize 3D volume data having grayscale values, this study adopt the Marching Cubes Algorithm [6]. This is a surface rendering technique which generates polygons making up equivalent surface for each cubic lattice of 8 voxels, visualizing approximate shapes (Fig. 3b).

step 1: All voxel values *P(x,y,z)* are compared with any threshold level *S* and a separation of $P \geqq S$ and $P < S$ is made.

step 2: The vertex of an equivalent surface *P* which exists in a reticular pattern is evaluated by the following linear interpolation using voxel values *P1, P2*.

$$P = (1 - A) \cdot P_1 + A \cdot P_2 \qquad (2)$$

where $A = (S - P_1)/(P_1 - P_2)$.

4. Result and Comparison

Fig.4 shows three grayscale images of snowflakes. These original images are captured by the three video cameras at 6:58 a.m. in February 26, 2005. "N" is north side, "E" is east side and "Up" is upper side of 2DVD sensor unit, N and E are from horizontal directions.

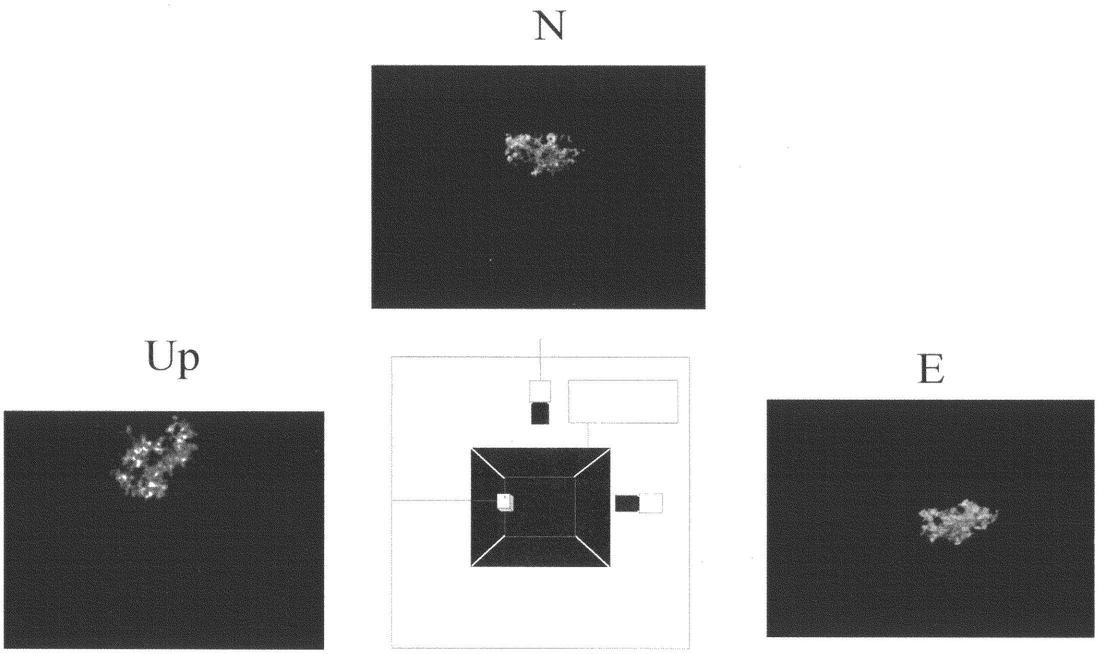
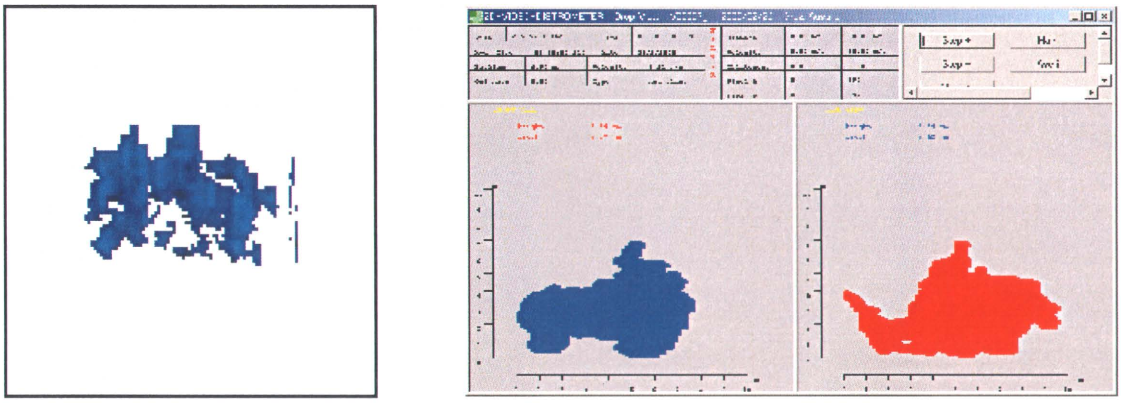


Fig.4 Original images from the three directions.

Fig.5a shows result of volume intersection and Marching Cubes after preprocessing. We can see that the 3D snowflake reconstructed by these techniques has the angular shape. This result leads to our presumption that some errors are observed due to not also the calibration error but Marching Cubes Algorithm itself. In other respects, the discontinuity of approximate shapes by many minute surfaces has something to do with the reason for the errors. The binary images as shapes of the snowflake is obtained by 2DVD for the reconstructed 3D image (in Fig.5b) and Table1 shows an example of all data of the snowflake from 2DVD.



a) 3D reconstruction image. b) Shapes of the same snowflake.

Fig.5 Results of two method.

Table 1 An example of all 2DVD data about one particle.

NUMERIC INFO ON SINGLE HYDROMETEOR:	
time	= 06:58:04.219
line of day	= 1286370229
equivolumetric diameter	= 6.900 mm
volume	= 172.002 mm3
vertical fall velocity	= 1.211 m/s
area for normalisation	= 9164.583 mm*mm
height of one line	= 0.023600 mm
type	= not class.

	FRONT (A)	SIDE (B)
height	6.891	6.891 mm
longest line	9.069	7.424 mm
number of lines	292	292
pixelwidth	0.159100	0.151500 mm

5. Conclusion

In this paper the 3D reconstruction for analysis of snowflakes is described, what is used the image data achieved by 2DVD and the three video cameras. Though there is a slight difference in shape between the obtained images, the silhouette image and the 3D reconstructed image, 3D data is useful for shape analysis. In concrete terms, the classification of snowflakes, or the analysis of volume, density, growth mechanism for the snowflakes will become available in the future. For the purpose of more exact reconstruction, the light adjustment and the improvement of the adopted algorithms are required.

References

[1] Mason B.J., Clouds, rain and rainmaking, Cambridge University Press, 1962.

[2] R. R. Rogers, M. K. Yau, A Short course in Cloud Physics, Butterworth-Heinemann, 1989.

[3] H. R. Byers, Elements of cloud physics, The University of Chicago Press, 1965.

[4] A. Laurentini, "How far 3D shapes can be understood from 2D silhouettes," *IEEE Trans. Pattern Analysis and Machine Intelligence,* 17(2), pp.18-26, 1997.

[5] W. Matusik, C. Buehler, R. Raskar, S. J. Cortler, and L. McMillan, "Image-based visual hulls," *Proc. SIGGRAPH'00*, pp.21-30, 2000.

[6] T. Matsuyama, T. Takai, X. Wu, and S. Nobuhara, "Generation, editing, and visualization of 3D video," *Trans. Virtual Reality Society of Japan*, vol. 7, No.4, pp.521-532, 2002.