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Research Article

A High-Speed All-Digital Technique for Agricultural Spray Measurement and Flow Visualization Image Analysis in Pesticide Application

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Abstract: In order to solve the faults in usual measurements of droplet distribution and motion in agricultural spraying field, a new method is given for the analysis of droplets characteristics and motion with PDIA (Particle/ Droplet Image Analysis) and digital image processing technique. During the analysis of the size of droplet and the velocity, images of droplets in spray field have been captured by using high-speed imager. The parameter of droplet such as size, perimeter, equivalent diameter, shape factor and position etc., have been calculated with digital image processing technology. The trace of droplet in different frames has been tracked with the method, which is based on flag tracking and droplet neighborhood matching probability technique. The results showed this method can both realize the motion trace of droplet in different image frames and analyses the velocity of droplet. This technique can detect the droplet parameters quickly and accurately for agricultural sprays and provide the basic way for research on flow visualization image analysis in pesticide application.

Keywords: Digital image processing, flow visualization, high-speed imager, PDIA

INTRODUCTION

Agricultural spray drift of pesticide is an important factor to cause environmental contaminations and low effectiveness of pesticide applications (Ucar *et al*., 2011). To analyze the drift affecting factors and the droplet drift dynamics could not only provide the theoretical basis for the research of the droplet drift control and the spraying equipment, but also increase the efficiency of pesticide applications, reduce the droplet drift and improve the environmental protection. There are many techniques were to develop a computer simulation model that mimics the collective behavior of droplets in the spray cloud form agricultural spraying field (Lu *et al*., 2012a, b). But on-target deposition and the related spray drift form field herbicide spraying operations are influenced by many factors, field tests to collect droplets data are very expensive and time consuming (Liu and Wang, 2009). It also finds difficulty in capture the image from the spray field in the traditional method of mechanical measurement (Chau, 2009).

Currently, three laser-based systems are commonly used to obtain information about spray clouds produced by agricultural nozzles (Heiskanen *et al*., 2008). These are Laser Doppler Anemometer (LDA), Particle Image Velocity (PIV) and Phase Doppler Particle Analyzer (PDPA). These methods can only measure the size and speed in a fixed position; they cannot get instantaneous entire flowing images. The Oxford Lasers VisiSize software measures Particle size and velocity distributions using a technique called Particle/Droplet Image Analysis (PDIA) (Lai *et al*., 2011). This technique will overcome the deficiencies all of the above method. In PDIA technique, a laser is used to illuminate the region of interest from behind and shadow images of the subject are taken with a digital camera (Yang *et al*., 2011). The laser and camera are triggered so that a single laser pulse freezes the motion of the subject during each frame capture (Deganello *et al*., 2011). In order to distinguish between the Particles and the illumination background, the system is capable of measuring Particles that are out of focus and Particles that are too far out of focus to be accurately measured and rejected (Xu *et al*., 2011).

To develop a new measurement method combining high-speed imager with all-digital image processing for the droplet size distribution and motion analysis in agricultural spray field, a new method is provided in this study to solve the faults in usual measurements of droplet distribution and motion in agricultural spraying field.

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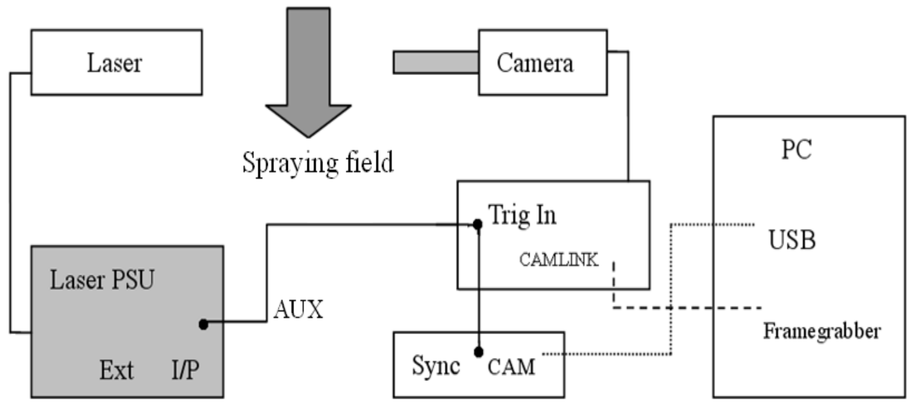

Fig. 1: Schematic of the system configuration for sizing

EQUIPMENTS AND METHODS

Experiment equipment: There are three main experiment equipments for measuring spraying field. One is Electrostatic Spraying Systems, another is Oxford Lasers Systems and the third is VisiSize 3.0 software. These apparatus and its schematic of the system conuration for sizing were shown in Fig. 1.

Calculation method: The shape parameters of the main characteristics of droplet include area, droplet equivalent diameter, droplet shape centre coordinates and shape factor. Calculated method as follows (Borkowski and Walczuk, 2011):

- **Droplet area (A_i):** If the droplet size image is $M \times N$ (pixels), droplet pixels in the image were labeled as $f_i(x, y)$, the formula of the droplet area is calculated as follows:

$$A_i = \sum_{x=1}^{M} \sum_{y=1}^{N} \left[f_i(x, y) / i \right] \tag{1}$$

- **Droplet equivalent diameter (D_i):** It was assumed that droplet image is a circular Particle shadows, the droplet equivalent diameter will be calculated as follows:

$$D_i = 2\sqrt{A_i / \pi} \tag{2}$$

- **Droplet shape centre coordinates (x_i, y_i):** For discrete digital image, the number of pixels at Δx is A_{ix} and at Δy is A_{iy}, the formula of droplet shape centre coordinates were calculated as follows:

$$\begin{cases} x_i = \dfrac{1}{MN} \sum\limits_{x=1}^{M} \sum\limits_{y=1}^{N} x A_{ix} \\ y_i = \dfrac{1}{MN} \sum\limits_{x=1}^{M} \sum\limits_{y=1}^{N} y A_{iy} \end{cases} \tag{3}$$

- **Droplet shape factor (φ):** Droplet shape factor ranged from 0 to 1, if it is close to 1, it shows approaching a full circular. On the droplet image, its shape factor was calculated as follows ("L_i" representing the perimeter of droplet):

$$\phi = 2\sqrt{A_i \pi} / L_i \tag{4}$$

- **Velocity of droplet motion ($\bar{v}_{Kx}$, $\bar{v}_{Ky}$):** If droplet shape centre coordinates at a image were x_{in}, y_{in} and to match adjacent to another droplet in the frame, the horizontal and vertical velocity of droplet will be calculated as follows:

$$\begin{cases} \bar{v}_{ix} = (x_{in} - x_{i1}) / [(n-1)\Delta t] \\ \bar{v}_{iy} = (y_{in} - y_{i1}) / [(n-1)\Delta t] \end{cases} \tag{5}$$

$$\begin{cases} \bar{v}_{Kx} = \dfrac{1}{m} \sum\limits_{i=1}^{m} \bar{v}_{ix} \\ \bar{v}_{Ky} = \dfrac{1}{m} \sum\limits_{i=1}^{m} \bar{v}_{iy} \end{cases} \tag{6}$$

The above formula: "Δt" representing the time different between two adjacent images that is the countdown to the camera's velocity of frame.

Experiment design: The experiment was carried on as follows condition: It was 20°C temperature, 10.2 kPa atmospheric pressure and 80% relative humidity in greenhouse. It was 0.4 MPa the nozzle pressure and 13.33 mL/svolume flow. Set as follows fixed coordinates: It is axial that spray nozzle along the direction in centerline of spraying and it is transverse that vertical to axis. Using two-dimensional measurement, launching systems and optical image acquisition device was set in the same level line.

Table 1: The characteristics of droplet size

Diameters		Microns
Mean diameter	Number mean ($D_{1,0}$)	12.7
	Volume mean ($D_{3,0}$)	15.9
	Sauter mean ($D_{3,2}$)	19.7
	Vol-wtd mean ($D_{4,2}$)	22.5
Volume percentiles	10% ($D_{v\,0.1}$)	13.1
	50% ($D_{v\,0.5}$)	23.4
	90% ($D_{v\,0.9}$)	30.6
Minimun	D_{min}	4.40
Maximun	D_{max}	31.1

Background ave: 162; Contrast: 0.47; Dark pixels (%): 2.22; Shape reject (%): 0; Particles/frame: 24.8; Elapsed seconds: 0

Table 2: The shape parameters of droplet

ID	Diameter/μm	Perimeter/μm	Shape factor
1	7.910	37.24	0.82
2	18.28	78.02	0.84
3	4.430	32.51	0.36
4	7.430	33.24	0.91
5	4.870	23.62	0.81
6	5.670	26.16	0.88
7	11.45	69.75	0.46
8	13.49	58.13	0.89
9	49.38	272.33	0.36
10	12.32	55.59	0.83
11	43.69	194.17	0.56
12	30.40	110.99	0.96
13	9.360	65.40	0.36
14	7.910	35.97	0.87
15	9.560	41.97	0.91
16	16.42	74.48	0.77
17	8.230	36.89	0.90
18	10.58	45.05	0.95
19	20.58	90.29	0.77
20	13.43	75.75	0.52
21	19.19	94.99	0.62
22	11.02	53.78	0.72
23	21.26	91.53	0.79
24	15.74	95.45	0.43
25	5.480	28.16	0.71
26	39.18	206.25	0.40

RESULTS AND ANALYSIS

Characteristics of droplet: Table 1 and 2 show the data for the droplets that have been analyzed. The equivalent diameter, perimeter, the shape factor and characteristics of droplet size are given for each numbered droplet. The data will be saved automatically as a binary report file (*.TXT).

Distribution of droplet: After configuring the image processing, as described above, a whole sequence of images to build up a size distribution and associated statistics can be analyzed. When a given sizing analysis is complete, the statistical data will be displayed in graphical on the results page, as shown in Fig. 2.

To pick up one frame from every ten images, there are 1495 droplets in total of 60 images. The accumulative distribution of droplets in different area and perimeter were displayed as shown in Fig. 3.

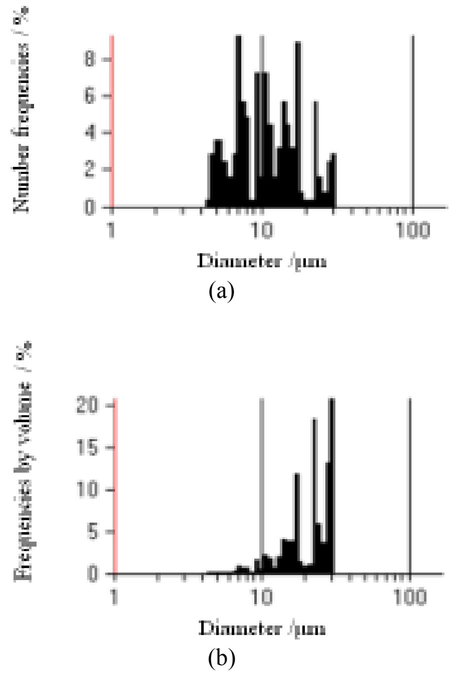

Fig. 2: Droplet size distribution, (a) diameter number frequencies, (b) diameter frequencies by volume

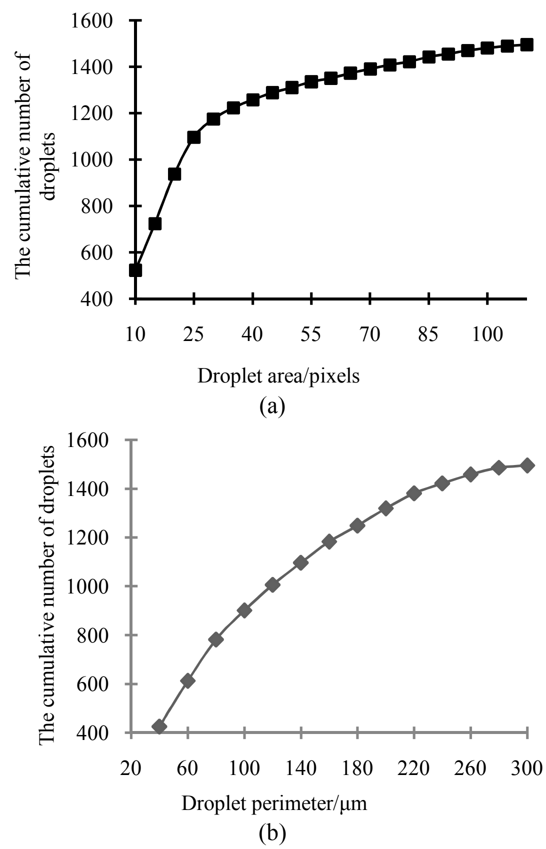

Fig. 3: The accumulative distribution of droplets in different area and perimeter size, (a) according to area of droplet, (b) according to perimeter of droplet

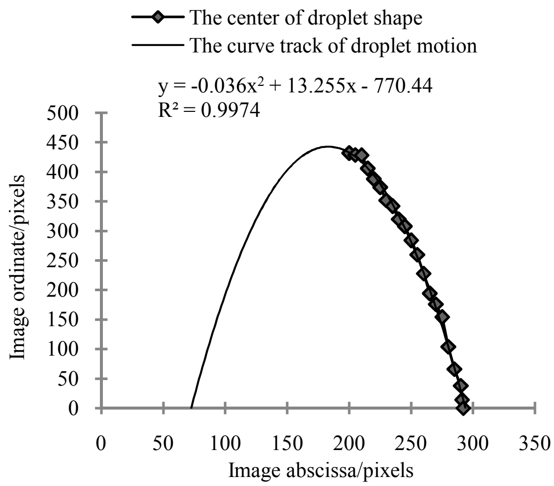

Fig. 4: The approximation in droplet trace

Analysis of droplet motion: Velocity data is obtained by VisiSizer using a technique called droplet tracking. During each frame of the camera the laser is pulsed twice with a pulse separation. The droplet pairs are linked with an arrow. And the numbers next to the droplets on the image correspond to the droplet numbers are given below for analyzing.

After the parameters of droplet such as size, the center of droplet shape and position etc., have been captured by high-speed imager and calculated with digital image processing technology, the 2-D (two dimensions) picture of droplet motion in spray field will be constructed according to these droplet parameters. The trace of droplet in different frames has been tracked with the method. The approximation curve track of droplet motion is shown in Fig. 4.

CONCLUSION

PDIA technique involves illuminating the subject from behind and taking shadow images with a digital camera. Any imaging set-up that allows Particles to cast distinct shadows can be used. This includes imaging suspended bubbles, as well as spray droplets or Particles in-flight. The high-speed imager can captured the shadow images at up to 100 frames/sec. The all-digital sizes each Particle based on the profile of its shadow and builds a size distribution by analysis many images. Velocity can also be measured using double-pulsed illumination, which causes each Particle to casts two distinct shadows in the same image. It is accurate and feasible to describe the droplets in the agricultural spraying field and to analysis flow visualization image in pesticide application by using PDIA measurement and all-digital image processing technique.

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REFERENCES

Borkowski, P. and E. Walczuk, 2011. Computerized measurement stands for testing static and dynamic electrical contact welding. Measurement, 44(9): 1618-1627.

Chau, T.T., 2009. A review of techniques for measurement of contact angles and their applicability on mineral surfaces. Miner. Engs., 22(3): 213-219.

Deganello, D., T.N. Croft and A.J. Williams, 2011. Numerical simulation of dynamic contact angle using a force based formulation. J. Non-Newton. Fluid, 166(16): 900-907.

Heiskanen, V., K. Marjanen and P. Kallio, 2008. Machine vision based measurement of dynamic contact angles in microchannel flows. J. Bionic Eng., 5(4): 282-290.

Lai, Y.X., S.Y. Chi and Y.H. Wang, 2011. Pesticide toxicity and selection for the pine wood nematode. J. Zhejiang Agric. Forest. Univ., 28(3): 479-485.

Liu, C.J. and K.Y. Wang, 2009. Atomization quality and charge performance experimentation research on air-assisted electrostatic spraying nozzle. J. Zhejiang Forest. Coll., 26(1): 116-121.

Lu, J., H.T. Zhang and D.Y. Wei, 2012a. Experimental computation process of the surface energy of leaves by acquiring drop image information. J. Nanoelectron. Optoe., 7(2): 173-176.

Lu, J., H.T. Zhang and D.Y. Wei, 2012b. A method for determining surface free energy of bamboo fiber materials by applying fowkes theory and using computer aided machine vision based measurement technique. J. Shanghai Jiaotong Univ. Sci., 17(5): 593-597.

Ucar, I.O., M.D. Doganci and C.E. Cansoy, 2011. Combined XPS and contact angle studies of ethylene vinylacetate and polyvinyl acetate blends. Appl. Surf. Sci., 257(22): 9587-9594.

Xu, D., I. Ametov and S.R. Grano, 2011. Detachment of coarse Particles from oscillating bubbles: The effect of Particle contact angle, shape and medium viscosity. Int. J. Miner. Process., 101(1-4): 50-57.

Yang, B., L. Cao and Y.P. Luo, 2011. Forced oscillation to reduce zero flow error and thermal drift for nonreciprocal operating liquid ultrasonic flow meters. Flow Meas. Instrum., 22(4): 257-264.