An Automatic Method Based on Image Processing for Measurements of Drop Size Distribution from Agricultural Sprinklers

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Abstract. The drop size distribution of sprinkler spray is of practical importance for two reasons. The first one is because the small droplets are subject to wind drift, distorting the application pattern. Second, large droplets possess greater kinetic energy which is transferred to the soil surface causing particle dislodgment and pudding that may result in surface crusting and runoff. We present in this paper a technique based on image processing for measure drop size distribution from agricultural sprinklers in automatic mode. This technique has the advantage of being a direct measurement method that allows to know the characteristics of agricultural sprinklers, which allows to study the effects of pressure and nozzle size on the distributions. The method was obtained using properties of the Fourier for correlation analysis in frequency domain. Results allow both farmers to change on existing irrigation systems to cope with field problems caused by low intake rates and runoff and development work to improve the uniformity of distribution of sprays from agricultural sprinklers.

Keywords: Image, Agricultural Sprinklers, Correlation

1 Introduction

Drop sizes have been measured by many researchers since 1890's. At least, six techniques for measuring drop size and distribution have been reported in the literature. They are the stain method [Wiesner, 1895; Lenard, 1904; Beker, 1907; Niederdorfer, 1932; Neuberger, 1942; Gillespie,1958; Hall, 1970], the momentum method [Hudson , 1981b; Joss and Waldvogel, 1967; Kinnell, 1976; Schleusener, 1971], the flour method [Bentley, 1904; Laws an Parson, 1943; Carter et al, 1974; Kohl, 1974], the immersion method [Fuchs and Petrjanoff, 1937; May, 1945; McCool, 1982], the oil method [Eigel and Moore, 1983]. Concerning to sprinkler jet breakup, the relatively high pressures used in sprinklers irrigation result in sufficiently high jet velocities for jet disintegration to occur in the secondary atomization region as defined by Miesse (1995). Moreover, as pressure is increased, in irrigation systems, the volume of water is applied as larger droplets decreased while there is a large increase in the volume applied as smaller droplets to make up the larger total discharge. Since jet velocity is proportional to the water pressure in a supply line, the higher pressures should produce greater relative velocities between the water and the air, resulting in a large number of smaller droplets. Kohl in 1974 shows that the drop size distributions from agricultural sprinklers followed the relationship of decreasing drop size with increasing relative velocity of the water to the air. Decreasing nozzle diameter decreased mean drop size by a greater amount. Also, the kinetic energy of the spray at the soil surface followed the same pattern.

On the other hand, during the past 26 years, there has been a considerable growth of interest in problems of pattern identification and image processing. This interest has created an increasing need for theoretical methods and experimental software and hardware for use in the design of pattern recognition, pattern identification, and image processing systems [Duda and Hart, 1973; Fukunaga, 1985; Fukunaga, 1990; Poggio and Edelman, 1990; Gouhara et al, 1992; Boninsegna and Rossi, 1994]. Drawing from its roots in traditional signals and systems theory, early image processing depended mainly on linear filters and convolution masks. Recently image processing has been mainly towards the development of, for instance, frequency analysis, non linear analysis, space-variant filtering, and model-based analysis, which are much more powerful

than the traditional techniques in handling the varied and challenging image processing tasks. Inside this context, the Fourier transform technique has still been widely used. A completely study of Fourier transform, its properties, and particularities may be found, for example, in Young and Sun Fu (1986). Due the computational efficiency, there is a natural choice for its use in applications with need of both image filtering and pattern matching. In this case, several applications can be done in which it is desired to know where a pattern image best fits within another. Moreover, because of the convolution theorem [Gonzales & Wintz, 1987], it is possible to make the correlation in the spatial domain or in the Fourier domain.

We present in this paper an automatic method based on image processing for measure drop size distribution of agricultural sprinklers.

2 Materials and Methods

To generate standards drops for the calibration of the method a surgical syringe with a hypodermic needle having an internal diameters of 0.45 mm was used, and drops were calibrated in volume by using a Mettler scaling model AE200. Additionally, by using the same set of needles and several number of drops, it was generated a complete calibration standard to be used for correlation analysis, and recognition. The petri dishes having standards drops for calibration were filled with a 2:1 mineral oil to a level approximately 3.5 mm below the ring of the dish i.e., 20 ml, to ensure that the oil is deeper than the diameter of the largest drop to be measured. Moreover, in order to avoid the dependency of the scale of the digitized images and the distance between the video camera and the petri dish it was also included at the neighborhood a visual pattern with a circular shape having a diameter of 10 mm, which allows corrections over an unknown radii or drop size, digitized from any distance, automatically. To collect the drop size distribution from agricultural sprinklers we used water sensitive paper from CIBA-GEIGY. The paper targets were rectangular and had dimensions of 2.5x7.5 centimeters and we digitized the images of the water sensitive papers using a conventional video camera model handycam Sony TR50BR and a MATROX PIP-640B digitized board. However, it is possible to use any system for image digitalization, as well as scanners. Figure 1 shows a petri dish having a set of generated patterns for calibration with volume ranging from 0.0054 cm^3 to 0.0810 cm^3 and respectively diameters ranging from 1.25 mm to 5.0 mm. Then, using the values obtained with the calibration procedure we interpolate and extrapolate volume of the drops versus diameters into a wide range of values. Table 1 shows both the correction factor values, which are the relation between the detected radii of the digitized drops and the radius of the circular pattern having 10 mm diameter, and the normalized drop volume i.e., in (cm^3/0.0054).

The use of table 1 allows not only to find the true volume of the drops but also the length of the radii in number of pixels. The correlation analysis technique was developed by means of the convolution theorem, in the Fourier domain. In the developed algorithm the correlation was obtained by using the inverse Fourier transform of the product of both Fourier transforms of an input image and a standard. Thus, by applying the theorem described above and using the notations XX(x,y), and HH(x,y) to represent respectively the input and the standard images we have:

$$XX(x,y) \circ HH(x,y) = \Im^{-1}\{ZZ^{*}(u,v) \cdot RR(u,v)\} \quad (1)$$

where $ZZ^{*}(u,v)$ is the conjugated of the Fourier transform of the input image, RR(u,v) is the Fourier transform of the standard image which has an unique circle i.e., with a approximated shape of a drop, with a known radius. The Fourier transform properties concerning to separability and periodicity were also used to obtain respectively a decrease of time processing and to allow the change of the quadrant for results visualization. Furthermore to represent the quantified values of the images it was used a gray-scale. The algorithm is outlined as a pseudo-code in table 2. The method assumes the use of a table to obtain the correct condition of searching the next drop of known radius, as well as to make corrections concerning to the digitizing process. Using a recursive way this task is repeat until the last significant drop size be found and identified.

For the implementation of the fast Fourier transform (FFT) it was used the radix-2 [Preuss,1982] with optimizations. The algorithm was implemented in the C++ language on a Silicon Graphics WorkStation, Indigo model, under an UNIX environment. The graphic interface was developed by using the 4D-Gifts from the graphics library of the Silicon Graphics WorkStation under a X-windows compatible environment.

3 Results and Discussion

Figure 2 shows the digitized images obtained from the water sensitive paper, which were sensibilized with drops from diverse agricultural sprinklers. In Figure (2-a) it is showed an image of drops from a spray of an agricultural sprinkler, collected by means of water sensitive paper and treated with a threshold area processing. In Figure (2-b) it is showed the image of a pattern to be recognized on the input image i.e. with a radius of 12 pixels. In figure (2-c) it is showed the Fourier spectrum of that input image. In Figure (2-d) it is showed a Fourier spectrum of the standard image. In

Figure (2-e) there is the correlation result by equation (1). In Figure (2-f) i.e., the output images, it is showed the recognized drop with radius equal to the standard. The process is repeated with a second standard image, which gives a second result until the identification of the drop with the smallest radius. Drop sizes ranging from less than 0.1 mm to over 85 mm in diameter have been successfully measured and automatically recognized. The accuracy was limited primarily by how accurately the calibration standards and area of the circular pattern were known. The method allows identification of drops smaller as one pixel, and automatically. Furthermore, by using an output periferic of the Silicon Graphics WorkStation, an report with the contents of the number of drops correlated with the known standards can be presented.

4 Conclusions

We presented in this paper a method for automatic drop size distribution identification from agricultural sprinklers. The method is based on correlation analysis in the frequency domain. Results show the suitability in terms of performance, applicability, processing time, and reliability, i.e., useful to be used for studying agricultural sprinklers in order to decrease problems concerning to soil erosion, aggregated breakdown, surface sealing, and infiltration.

5 Acknowledgment

The work reported in this paper was supported in part by Grants Numbers 12.0.94.090, and 12.0.94.093 from the Brazilian Enterprise for Agricultural Research (EMBRAPA), and No. 90/3773-7 from the Researcher Support Foundation of the State of São Paulo (FAPESP). The authors wish also to thank the Department of Computer Science of the Federal University of São Carlos.

Normalized Drop Volume [cm^3/0.0054]	Correction Factor
1	1.25
2	1.87
3	2.50
4	2.81
5	3.12
6	3.43
7	3.75
8	4.06
9	4.37
10	4.68
11	5.00
12	5.31
13	5.56
14	5.68
15	5.87

Table 1 - The correction factor values, which are the relation between the detected radii of the digitized drops and the radius of the circular pattern having 10 mm diameter i.e, the normalized drop volume in (cm^3/0.0054).

```
begin00
      FigXX = Source Picture;
      FigCal = Picture for Calibration;
      NPT1 = Number of Known patterns;
      NPT2 = Number of elements in volume;
      Single_Drop_Volume = 0,0054; //* volume in ml*//
      Radius = initial radius; // *( example: initial radius = 20 pixels )*//
      FigAX = FigCal;
     MakePattern (Radius) in FigHH;
     FigCor = Correlation of FigAX with FigHH;
      biggest = The biggest pixel value on FigCor;
     for PT = 0 to NTP1 do begin01
               If (Table[PT].Correlation = biggest (±1.5%)) and
                    (Table[PT].ActualRadius = Radius) do
                         Radius = Table[PT].RealRadius;else "Error";
                              end01;
     StandardPatternRadius = Radius; // *Radii in pixel*//
     K = (KnownRadius/StandardPatternRadius); //* Correction factor*//
while Radius< > 0 do    begin02
                    FigAX = FigXX; //* The source Picture*//
                    Make Patterns (Radius) in FigHH;
                    FigCor = Correlation of FigAX with FigHH;
                    biggest = The biggest pixel value in FigCor;
                    FigMap = Picture with the biggest occurence value only;
                    for PT = 0 to NTP1 do begin03
                         If (Table[PT].Correlation = biggest (±1.5%)) and (Table[PT].ActualRadius = Radius) do
                                   Radius = Table[PT].RealRadius;
                         else Radius = 0;
                         end03;
                    RealOftenCont = Number of "Clusters"in image FigMap;
                    Rmm = Radius*K; //* Calculation of the radii in millimiters *//
                    KR = Radius/StandardPatternRadius; //* Calculation of the volume*//
                    for PT = 0 to NPT2 do
                         If (KR = TableVol[PT].KR (±1.5%)) do
                              Volume = PT*Single_Drop_Volume;
                    Display("There are", RealOftenCont," Drop of radius", Rmm);
                    Display("with Volume ",Volume, " ml");
                    FigCX = FigCX minus the recognized patterns;
               end02;
      Display ("The sprinkler was analyzed.");
end00.
```

Table 2 - The algorithm outlined as a pseudo-code

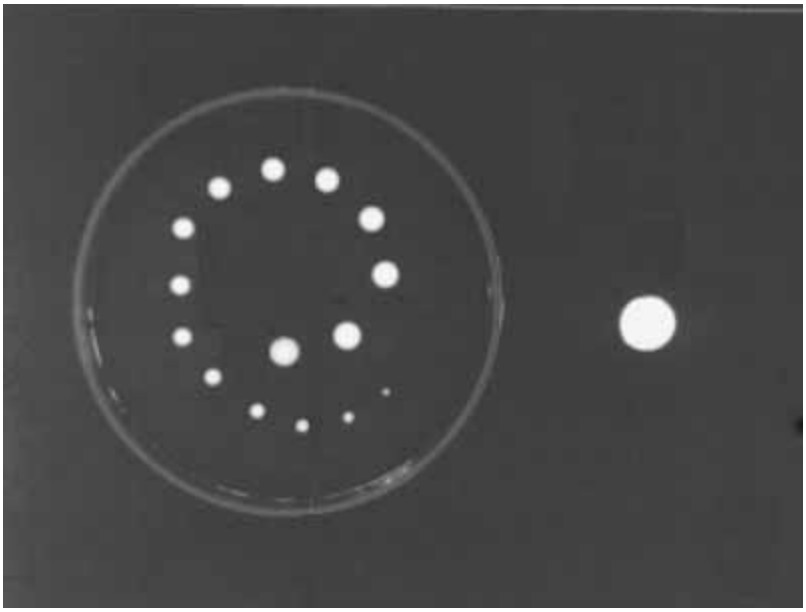

Figure 1 - A petri dish having a set of generated patterns for calibration with volume ranging from 0.0054 cm^3 to 0.0810 cm^3 and respectively diameters ranging from 1.25 mm to 5.0 mm.

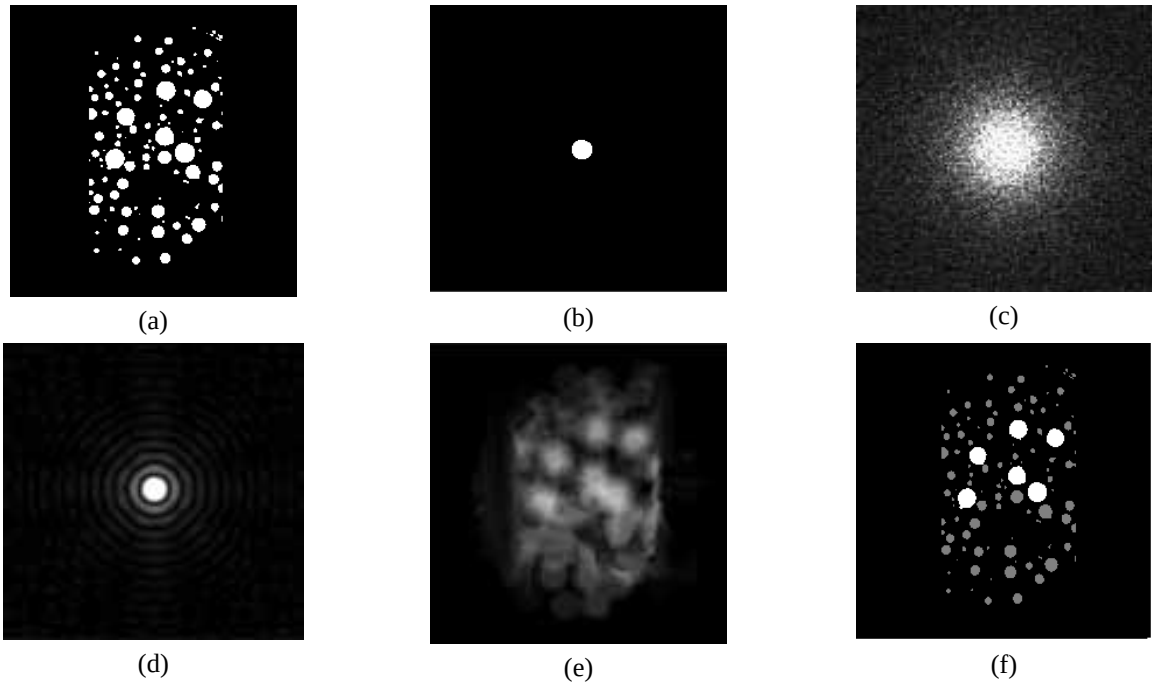

Figure 2 - a) an image of drops from a spray of an agricultural sprinkler, collected by means of water sensitive paper and treated with a threshold area processing; b) the image of a pattern to be recognized on the input image i.e. with a radius of 12 pixels; c) Fourier spectrum of the input image; d) Fourier spectrum of the standard image; e) correlation result f) the output images showing the recognized drops.

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