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Image based techniques for determining spread patterns of centrifugal fertilizer spreaders

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Abstract

Precision fertilization requires new techniques for determining the spread pattern of fertilizer spreaders. Because of the accuracy and non-intrusive nature, techniques based on digital image processing are most promising. Using image processing, dynamics of particles leaving the spreader can be determined. Combined with a ballistic flight model, this allows predicting the landing position of individual fertilizer particles. In a first approach, a two-dimensional imaging technique was used with small field of view (0.33 m on 0.25 m). In the second approach, a larger field of view (1 m on 1 m) was used. To improve the accuracy of previous technique, binocular stereovision was used to determine three-dimensional information.

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*Keywords:*Spread pattern; image techniques; cross correlation; ballistic flight; fertilizer.

1. Introduction

Precision fertilization requires the right amount of fertilizer to be placed at the right moment at the right spot. This

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implies amongst others that the spreader used must be precisely controlled and adjusted, depending on the working conditions, the type of fertilizer and the optimal fertilizer distribution. Although the centrifugal fertilizer spreader is most commonly used in practice, its controllability and adjustability are rather limited. Nowadays, spreader adjustment is often neglected because of the labor intensive and time consuming nature of spread pattern determination (Tissot et al., 2002). High speed image processing is becoming more of interest in agricultural applications (Hijazi et al., 2012; Vulkagaris Minov et al., 2015). Using this technique to determine dynamics of fertilizer particles on the flight, combined with ballistic flight models (Cool et al., 2014), has the potential to overcome most of these problems (Cointault and Vangeyte, 2005). Therefore, the Flemish Institute for Agricultural and Fisheries Research (ILVO) and its partners are exploring and developing accurate and time efficient techniques to measure the spread pattern of centrifugal fertilizer spreaders using image processing. The requirements of the system are:

- The system should be mobile so that it can be used at farm level to test several combinations of machine settings and fertilizer types in a short timeframe;
- It should enable the adjustment of the spreader in such a way that the desired spread pattern is obtained;
- The technique has the potential to allow future development of a low cost and onboard system, allowing for a continuous adjustment and control in the field.

2. Previous developments and approaches

Traditionally, the spread pattern is determined by measuring the fertilizer distribution on the ground. In order to be able to respect the above mentioned requirements under all conditions, however, it was opted for to predict the distribution based on individual particle landing positions. Theoretically, this could be done via the combined simulation of the movements of fertilizer particles on the centrifugal disks on the one hand and the flight of these particles in the air after leaving the disk. As the simulation of the particle behaviours on the disk is much more difficult (time consuming and higher uncertainty on the results) than the simulation of the flight in the air (where particles are further apart and thus hardly interacting), a hybrid approach combining measurements and simulations was proposed: particle diameter, initial velocity, horizontal and vertical outlet angles are measured via processing of images taken just after leaving the disk and used as inputs to a ballistic flight model, which predicts the landing position relative to the disk. Combining the landing positions of all particles leaving the spreader results in the overall spread pattern.

3. Two-dimensional technique

As a first step, a two-dimensional imaging technique was used with a small field of view (0.33m x 0.25m) to measure the horizontal outlet angles and the velocity of the particles at different camera positions at the circumference of the disk. The vertical outlet angle and the mass distribution were measured with a cylindrical collector. The grains flying under the measurement unit were imaged using two different techniques: (1) high speed imaging technique and (2) a newly developed multi-exposure (stroboscopic) imaging technique (see Fig. 1). Overall, the stroboscopic technique and the high speed technique were capable of measuring the outlet angle and the outlet velocity satisfactorily (average relative difference was less than 1% for the horizontal outlet angle and 2% for the horizontal velocity). The values obtained using the image processing techniques were subsequently used for simulation of the ballistic flight and the resulting spread pattern. Comparison of this spread pattern with the spread pattern determined with the traditional technique, revealed relative errors of up to 30%. More details can be found in Vangeyte and Sonck (2007) and Hijazi et al. (2014a).

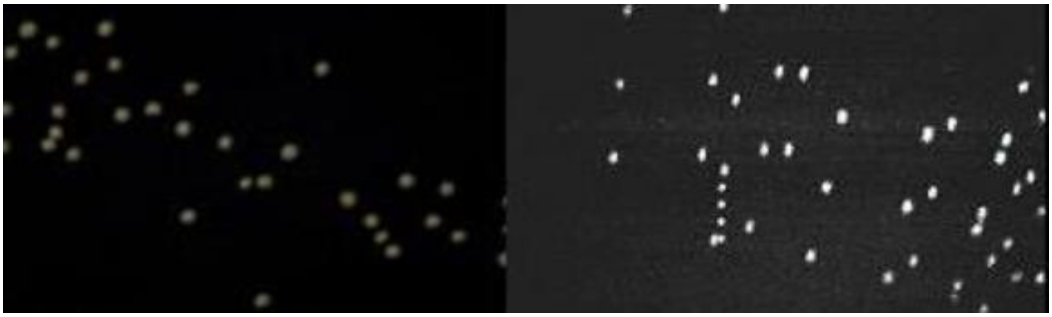

Fig. 1. Particle images for the high speed (left) and stroboscopic (right) imaging technique.

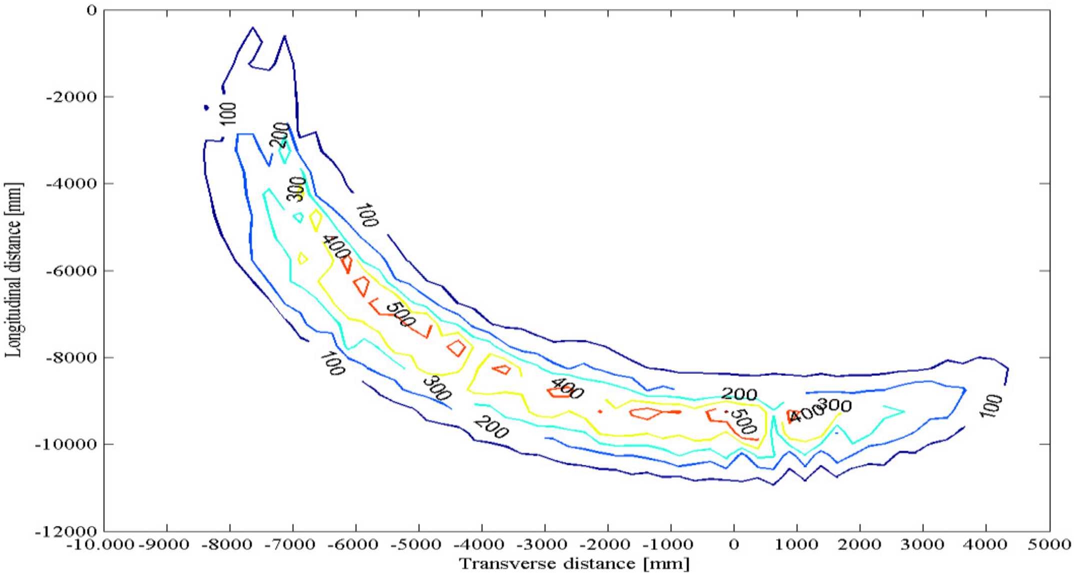

Fig. 2. Spread pattern of a test spreader resulting from measurement with stroboscopic technique.

4. Three-dimensional technique

In the previous approach, no depth information can be obtained due to the fact that only one camera was used, causing inaccuracies in the information extracted from the images. To improve the accuracy of the system, stereovision was introduced to estimate particle movement and position in three dimensions. A binocular stereovision setup of two high speed cameras was used and a large field of view (1 m on 1 m) was applied. For more details on the setup, we refer to Hijazi et al. (2014b). The subsequent steps of the image processing algorithm are illustrated in Fig. 3. In a first step, two subsequent framesets (a frameset is defined as one image from each camera) are acquired. Each frameset is taken on a specific time instance; the time between the acquisitions of both framesets is set by the frame rate of the camera. Secondly, the particles are segmented from the background and noise. In a third step, particles are matched between the left and right image (stereo matching) on each frameset. Based on the camera configuration and difference in position between the particles in these two images, the 3D position of the particles can be determined at two subsequent time instances. In a next step, the particles are matched in time: for each particle in the image of one camera, the corresponding particle in the next image is searched. This step is illustrated in Fig. 4. Finally, based on the difference in 3D position between the two time instances and the frame rate of the camera, the particle 3D velocity is determined. For more details, we refer to Hijazi et al. (2010, 2011, 2014b).

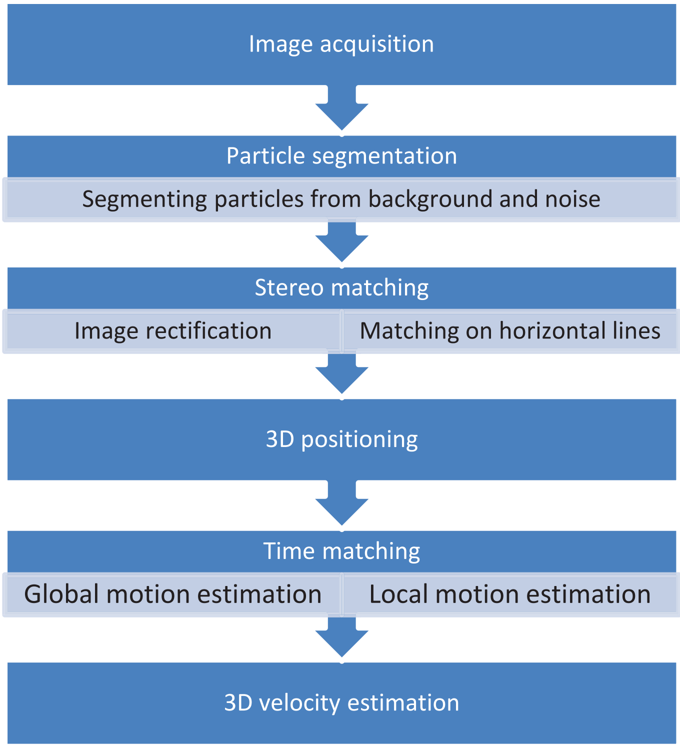

Fig. 3. Flowchart of algorithm for 3D position and velocity estimation of fertilizer particles

Although the results showed to be promising, the particle resolution on the images was too low, introducing matching errors and inaccuracies in the 3D positioning (Cool et al., 2015).

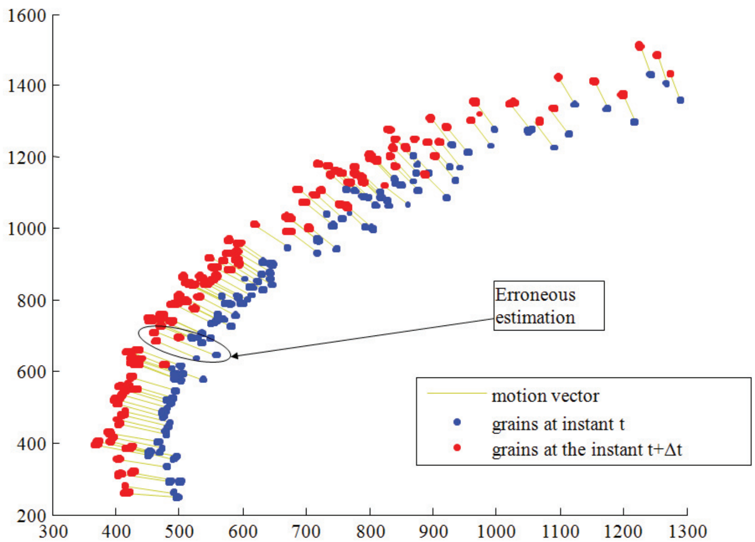

Fig. 4. Results from time matching algorithm for a throw of fertilizer particles (two different time instances)

4. Ongoing research

At the moment, a small field of view (for the sake of increased particle resolution on the images) high speed stereovision system is being developed in combination with adapted motion estimation algorithms and an improved ballistic model. High speed image acquisition is combined with a newly developed high illumination system for multi exposure, which enables the reliable and time efficient estimation of the spread pattern under controlled conditions. The usefulness of the proposed techniques for outdoor application is not yet evaluated.

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