A 3-D STEREOVISION SIMULATOR FOR CENTRIFUGAL FERTILIZER GRANULE SPREADING

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ABSTRACT

Imaging systems, specifically stereo rigs, are becoming more widely used in several domains. In precision agriculture stereovision can be used to characterize the fertilizer centrifugal spreading process and to control the spreading fertilizer distribution pattern on the ground. The final goal is to improve spreader performances and come to a better distribution of the grains in the field. Fertilizer grains are all very similar and the grain images are of low quality regarding the texture aspect. Therefore the accuracy of stereo matching algorithm in literature can't be used as a reference for a stereo images of fertilizer grain.

In order to evaluate stereo matching algorithms applied on particle images on such images, a generator of synthetic stereo particle images is presented in this paper. The particle stereo image generator consists of two main parts: a 3d particle position generator and virtual stereo rig. The 3d particle position generator uses a ballistic flight model and the disc characteristics to simulate the ejection and the displacement of grains. The virtual stereo rig simulates the stereo acquisition system and it generates a stereo images, a disparity map and an occlusion map. Evaluated matching algorithms are applied on the generated stereo images. The obtained results are compared with the disparity and occlusion map to calculate their accuracy.

Keywords: Fertilizer centrifugal spreader, Stereovision, Image Processing.

INTRODUCTION

Imaging systems and image processing techniques evolved considerably in the last decade. With this evolution the use of imaging techniques to resolve research problems increased. In fluid mechanics domain where the study of the fluid turbulences is essential, techniques such as Particle Image Velocimetry (PIV) (Agüí and Jimenéz, 1987; Foucaut et al., 2004; Melling, 1997; PUST, 2000; Westerweel, 1993) and Particle Tracking Velocimetry (PTV) (Adamczyk and Rimai, 1988; Agüí and Jimenéz, 1987; Grant, 1997) are mainly used to characterize the turbulences. In the recent years PIV and PTV in 3D has received more interest from the scientific community (Hori, 2004; Hori and Sakakibara, 2004; Ponchaut et al., 2005).

In precision agriculture, image processing coming from PIV technique was used to estimate the motion of fertilizer grains ejected by centrifugal spreaders (Hijazi et al., 2010b; Hijazi et al., 2011). Many factors, such as construction and calibration of the machinery, particle types and properties, field conditions, etc. influence the distribution pattern of centrifugal fertilizer spreaders in the field (Cointault et al., 2008; Hijazi et al., 2010c; Hijazi et al., 2011; Van Liedekerke et al., 2009; Villette et al., 2008).. Maladjusted centrifugal spreaders create uneven distribution with economical and environment consequences.

In a previous work (Hijazi et al., 2010a; Hijazi et al., 2010d), we showed the feasibility of using stereovision to characterize the fertilizer centrifugal spreading process and to control the spreading fertilizer distribution pattern on the ground. Fertilizer grains are similar and the grain images are poor according to texture aspect. Therefore the accuracy of stereo matching algorithm in literature cannot be used as a reference for a stereo images of fertilizer grain. The final goal is to improve spreader performances and come to a better distribution of the grains in the field. In order to evaluate the stereo image matching algorithm applied on stereo particle images, we present in this paper a generator of stereo particle images.

MATERIALS & METHODS

The stereo particles image generator consists of two main parts : the 3d particle position generator and the virtual stereo rig.

The 3d particle simulator

The 3d particle simulator generates the 3d coordinates and the size of particles. We suppose that the particles are spherical. The output of the simulator depends on the application. Particle positions and sizes can be randomly generated or can be calculated using a modeling of the process in question.

Virtual stereo rig

The pinhole model (Roberts '65; Hartley and Zisserman '00) is used to simplify the camera system.. The pinhole camera is modeled by an image plane, an optical center C and the focal length f which is the distance between C and the image plane. The projection point M of a world 3D point P into an image is the intersection of the line joining C and P (figure 1). Hence two characteristics of cameras, pixels dimension and sensor resolution, and the focal lens are needed to simulate a camera by a virtual camera.

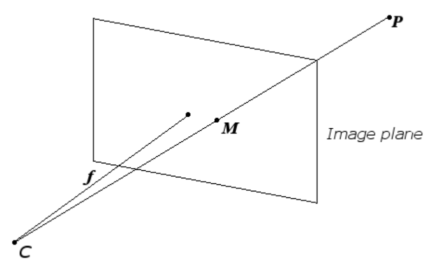

Fig. 1. Pinhole model

In addition the virtual stereo rig is a binocular rig. We suppose that both cameras are parallel. Therefore the translation between cameras should be known.

The outputs of virtual stereo rig are the stereo images, the disparity map and the occlusion map. The procedure for the creation of the right and the left image is explained.

First, lines are drawn from the left optical center (C_L), through the center of each pixel. Let L be the line and $\boldsymbol{p_L}$ the pixel. When the line L crosses a sphere (particle), the grey level of the pixel $\boldsymbol{p_L}$ (Figure1) changes. The value of the grey level is determined by a Gaussian. The maximum of the Gaussian corresponds to the center of the sphere. The final value that is assigned to the pixel is proportional to the distance between the sphere and the optical center. This results in the simulated left image.

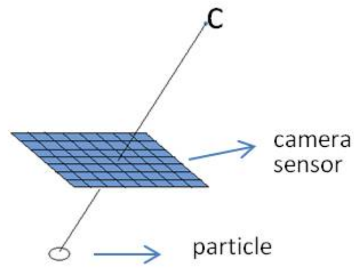

Fig. 2. Illustration of the virtual image acquisition process. C is the optical center

Next the right image is simulated. The intersections between L and the spheres (particles) are connected to the right optical center C_R by a line L_R. If L_R crosses another sphere in the direction of C_R , the pixel in the occlusion map corresponding to $\boldsymbol{p_L}$, is put to one. The occlusion map is an image matrix of the points in the field of view that can only be seen in the left image. In the other case, a grey level is assigned to the pixel $\boldsymbol{p_r}$ on the intersection between the $\boldsymbol{L_R}$ and the right image plan. In addition, the disparity map pixel that corresponds to $\boldsymbol{p_L}$ is put to $\boldsymbol{d=x_l-x_r}$ ($\boldsymbol{x_l}$ and $\boldsymbol{x_r}$ are respectively the abscissa of $\boldsymbol{p_l}$ and $\boldsymbol{p_r}$) in the right image. The centers of pixels that are not assigned with a grey level are connected to optical center with a line R. If the line R crosses a sphere then the grey level, determined by the Gaussian and the distance is assigned to the pixel. The method is summarized schematically in figure 2.

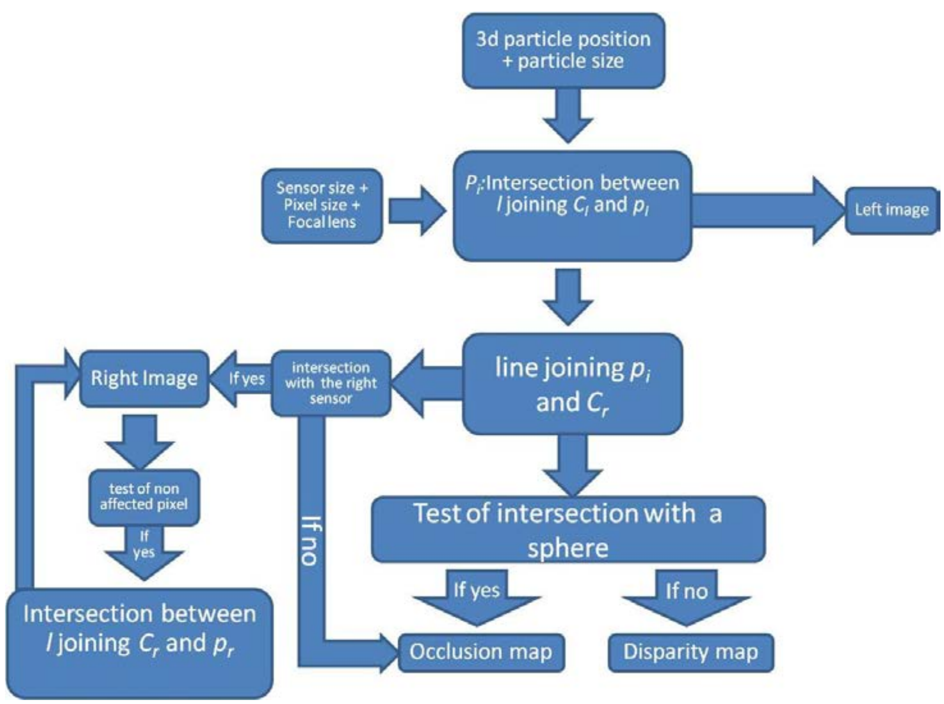

Fig. 3. Graph illustrating the algorithm used to create stereo images, the disparity map and the occlusion map. $\mathbf{l}$ is a line. $\mathbf{C_l}$ and $\mathbf{C_r}$ are respectively left and right optical center. $\mathbf{p_l}$ and $\mathbf{p_r}$ are respectively left and right sensor pixel center.

RESULTS

The virtual stereo system used in the follow tests has the characteristics below:

- Focal lens: 24 mm
- Pixel size: 12µm x12 µm
- Sensor size: 2000x2000 pixels
- Camera distance: 2000 mm

Two cases were tested: random particle generation and a particle generation for fertilizer centrifugal spreading application.

Random particle generation

Two thousands particle 3d positions were randomly generated. The particles are all included in a volume of 1m x 1m x 0.2 m (figure 4).

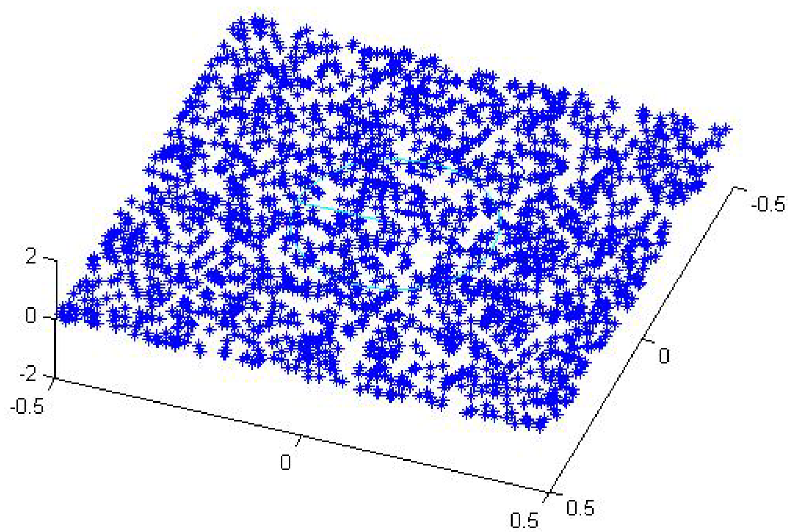

Fig. 4. particles position randomly generated

Figure 5 showed the resulting stereo images, the disparity map and the occlusion map.

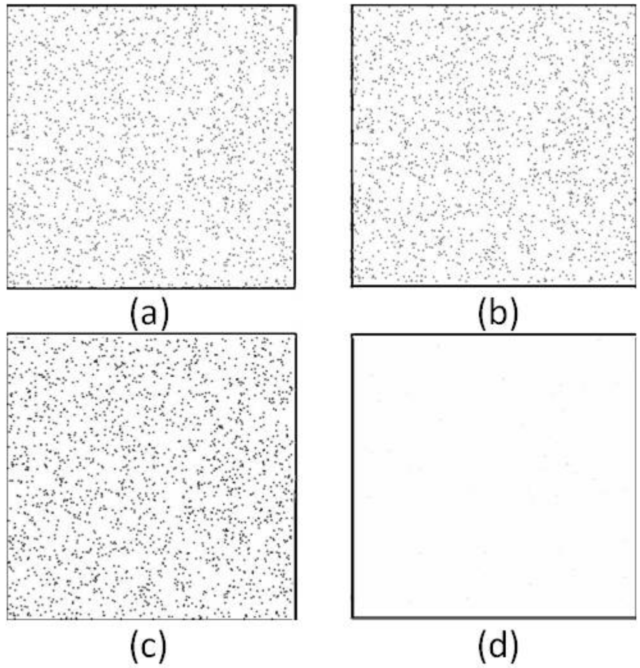

Fig. 5. Resulting images of a random particles position simulation. Grey levels are inverted in the images,(a) shows the left stereo image and (b) show the right stereo image. (c) and((d) show respectively the disparity and occlusion map.

particle generation for fertilizer centrifugal spreading application.

The centrifugal spreader consists of a spinning disc equipped of vanes that eject fertilizer grains with a speed of 40 $m.s^{-1}$ (figure 6).

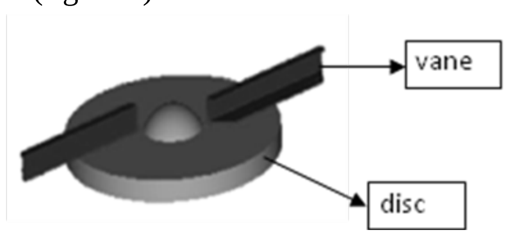

Fig. 6. Centrifugal spreader disc and vanes.

Therefore a ballistic flight model (WEB 1) is used to generate particle coordinates. To calculate the particle position several parameters need to be known :

- rotation speed of the spreader disk
- vane length
- mean vertical ejection angle
- mean horizontal ejection angle

mean particle size

Figure 7 shows the calculated coordinates with :

- rotation speed of the spreader disk :800 tr/min
- vane length: 300 mm
- mean vertical ejection angle: 6°
- mean horizontal ejection angle: 50°
- mean particle size: 5mm

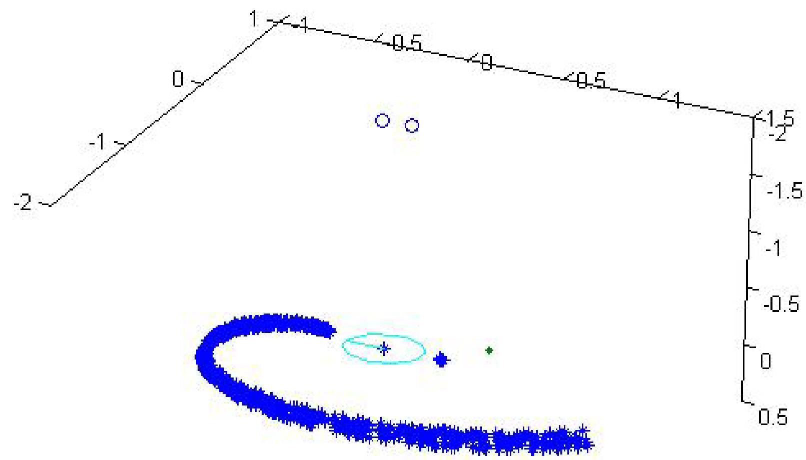

Fig. 7. the two small circle on the top of the image represent the cameras, the circle at the position (0,0,0) represent the disk and the arc shaped cloud of points represent the centers of particles .

Using the calculated positions, images presented in the figure 7 are obtained from the stereo virtual rig.

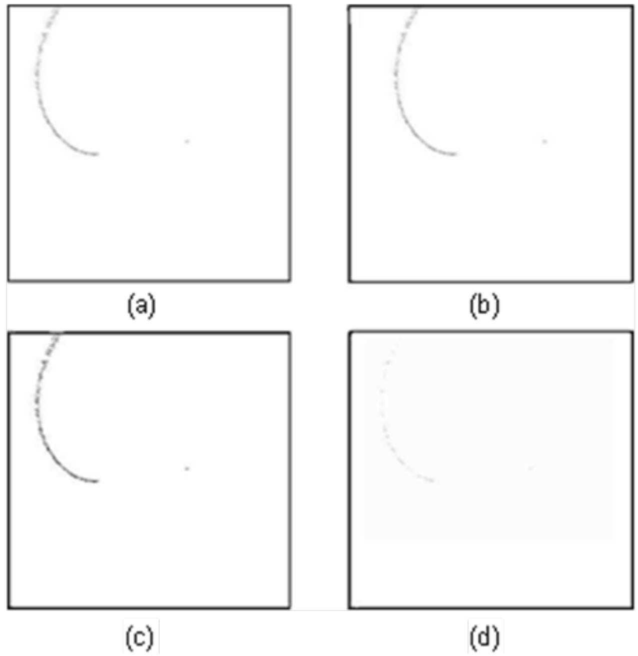

Fig. 8. resulting images of a fertilizer grain centrifugal spreading simulation. Grey levels are inverted in the images,(a) shows the left stereo image and (b) show the right stereo image. (c) and((d) show respectively the disparity and occlusion map.

CONCLUSION

We presented in this paper a particle stereo image generator. The output of the generator is the stereo images, disparity map and the occlusion map which can be used to evaluate the stereo matching algorithms used on stereo images of particles such as fertilizer grains.

In a future work the generator will be evolved to generate images of particles in motion in order to evaluate 3d motion estimation methods applied on particles motion.

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