

# Method and Experiment for Measuring Grain Flow based on Multi-View Stereo Vision

Qibin Li

School of Agricultural Engineering, Jiangsu University, Zhenjiang, Jiangsu 212013, China

---

## Abstract

The yield monitoring system is a key technology for real-time acquisition of yield data and refined field management in precision agriculture. This paper focuses on the scraper elevator of a large combine harvester and proposes a real-time measurement method for grain flow based on multi-view stereo vision. A discrete element simulation was conducted to analyze the grain conveying process of the scraper elevator, examining the accumulation state of the grain above the scraper. By installing auxiliary light sources on the scraper's sidewall and using multiple industrial cameras to capture images from different angles of the scraper's side and front, high-speed modeling and volume measurement of the accumulated grain on the conveying scraper were achieved through multi-view 3D reconstruction technology, enabling the detection of grain flow during the harvesting process.

## Keywords

Multi-View Stereo Vision; 3D Reconstruction; Yield Monitoring; Precision Agriculture.

---

## 1. Introduction

In harvesting operations, information on crop yield distribution is an important indicator for evaluating agricultural production efficiency, and an accurate and reliable yield monitoring system is the key foundation for real-time yield information acquisition by harvesters. Yield monitoring systems have matured in developed agricultural countries, such as high-end intelligent combine harvesters produced by companies like John Deere, Claas, and New Holland, which can acquire location and yield information in real time during harvesting and generate yield maps. However, the relevant technologies are blocked in China.

Grain flow sensors are core components of yield monitoring systems, with measurement principles mainly including impulse measurement, volume measurement, ray measurement, dynamic weighing, and other types. In terms of impulse measurement, companies like John Deere and New Holland utilize this method, with John Deere's S series harvesters employing a multi-point calibration method. The AFS grain flow monitoring system developed by Case is currently the most accurate among commercial products of this type. To improve the accuracy of impulse measurement, researchers at South China Agricultural University, led by Hu Junwan, designed a dual-plate system based on a single plate, using mechanical damping and differential circuits to reduce interference from machine vibrations. Impulse sensors have a simple structure and low cost, but they face installation difficulties due to the positioning of the auger in the combine's grain tank.

Photoelectric sensors are easy to install and highly versatile. Commercial yield monitoring systems from Japan's Topcon and the U.S.'s Raven companies both utilize this method. While photoelectric measurement is convenient and versatile, it is susceptible to false triggering caused by falling grains. In terms of other measurement methods, Zhang Huicui and colleagues from China Agricultural University applied gamma-ray sensors for yield monitoring, achieving high accuracy, but the harmful electromagnetic radiation makes it unsuitable for widespread use. Zhang Xiaochao and colleagues

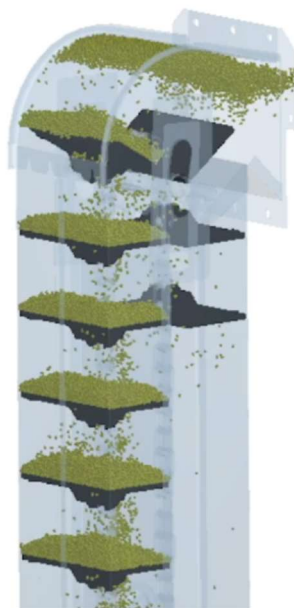
from the Chinese Academy of Agricultural Sciences obtained yield information through dynamic weighing of the auger inside the grain tank, achieving high accuracy, but this method requires significant modifications to the harvester and has low versatility.

Compared to traditional measurement methods, visual measurement technology has gained significant research applications due to its rich information and reliable intelligence. For example, Yang Gang from Shanghai Jiao Tong University measured the thickness of grain on the scraper using line structured light measurement models to obtain volume flow, but the volume model constructed was a standard rectangular prism and did not account for the effects of grain fall. Jiang Xin from Nanjing Agricultural University calculated the cross-sectional area of grain flow by capturing the grain flow profile of a horizontal auger, achieving the volume of grain flow. However, this measurement method relies on horizontal screw augers for quantitative transport and lacks versatility. Therefore, this paper explores the technology of multi-view 3D reconstruction to achieve high-speed modeling and volume measurement of accumulated grain on the conveying scraper, enabling real-time measurement of grain flow during the harvesting process.

## 2. Materials and Methods

### 2.1 Design of Grain Flow Visual Monitoring Sensor

To obtain the grain accumulation pattern under normal working conditions of the scraper elevator, this study conducted a discrete element simulation of the grain conveying process. First, a three-dimensional model of the scraper elevator was created using SolidWorks, with the scraper material being rubber and the elevator positioned vertically to the ground. To reduce the computational load of EDEM software and improve calculation efficiency, the elevator device was simplified, retaining only key components such as the elevator shell, scraper, and chain. After modeling, the model was imported into EDEM software. Before solving the simulation calculations, measurements were taken of randomly selected wheat grains, measuring 100 rice grains with an average size of  $6.65 \text{ mm} \times 3.48 \text{ mm} \times 3.23 \text{ mm}$ . In EDEM software, these were represented using nine spherical particles. The rotation speed of the elevator's auger was set to 340 rpm, consistent with the machine's operation. The modeling and discrete element simulation of the scraper elevator are shown in Figure 1. The simulation parameters for the wheat grains are listed in Table 1.



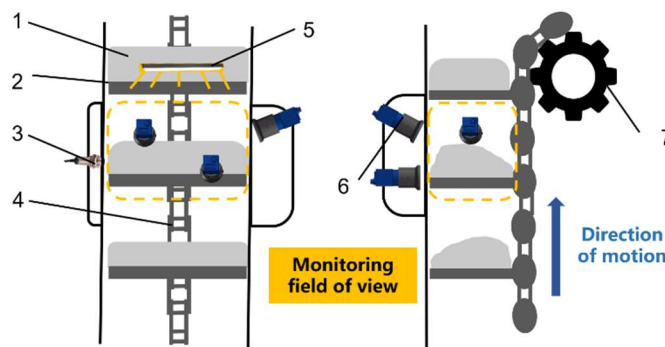
**Figure 1.** Discrete Element Simulation of the Scraper Elevator Operation

**Table 1.** Simulation Parameters for Wheat

Simulation object	simulation parameter	value
The wheat has a plump grain	Dimensions (length × width × height) mm	6.65×3.48×3.23
	Poisson's ratio	0.25
	Shear modulus /Mpa	2.33×102
	Density (kg/m <sup>3</sup> )	1350
Carbon steel metal (auger, chain, etc.)	Poisson's ratio	0.25
	Shear modulus /Mpa	2.33×102
	Density (kg/m <sup>3</sup> )	1350
Rubber scraper	Poisson's ratio	0.3
	Shear modulus /Mpa	2.3
	Density (kg/m <sup>3</sup> )	1385

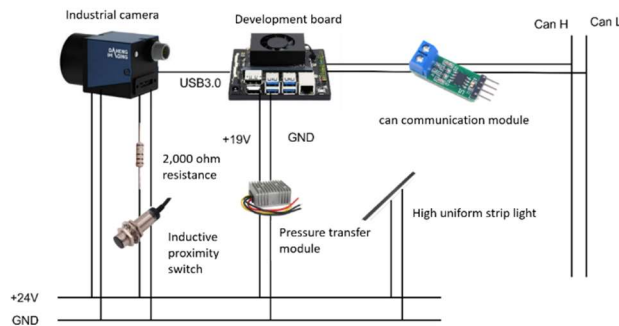
Through the simulation interface, it can be observed that during the grain conveying process in the elevator, the accumulation patterns of the grain appear from different perspectives, such as the front and side of the scraper. As the elevator operates, the grain is constrained not only by the elevator's shell but also influenced by the scraper, chain, and its own gravity. Therefore, wheat grains typically exhibit irregular shapes on the actual scraper elevator.

The rubber scraper measures 250 mm in length and 150 mm in width, with a distance of 150 mm between adjacent scrapers. To meet the requirements for monitoring the field of view and object distance for the conveying scraper, hardware selection was conducted for components such as the camera lens. After evaluating the uniformity of lighting from different types of light sources, including linear and ring lights, the S-135-12 auxiliary light source was chosen. Based on the multi-view monitoring method of the camera, components such as the camera, lens, light source, and proximity switch were integrated to design the grain flow sensor. The installation method of the sensor is shown in Figure 2.



**Figure 2.** Installation of the Visual Monitoring Sensor

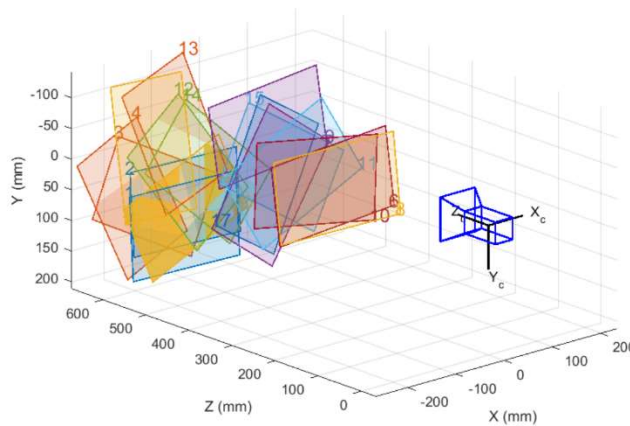
The visual yield monitoring system developed in this paper primarily includes a camera, lens, light source, proximity switch, NVIDIA development board, and CAN communication module. The industrial camera is used to capture raw images of grain accumulation from different angles on the scraper. To ensure that multiple cameras can simultaneously capture high-quality images of grain accumulation from different perspectives, the proximity switch is utilized as an external trigger source to detect scraper movement. A hard-trigger acquisition circuit is built using the camera's IO interface, transmitting the captured images to the NVIDIA development board, which establishes communication with the host computer through the CAN communication module. The architecture of the visual monitoring sensor is shown in Figure 3.



**Figure 3.** Components of the Visual Monitoring Sensor Architecture 1.Piled grain 2. Scraper 3. Proximity switch 4. Chain 5. Strip light source 6. Industrial camera 7. Sprocket

### 2.2 3D Reconstruction and Volume Measurement of Grain Accumulation

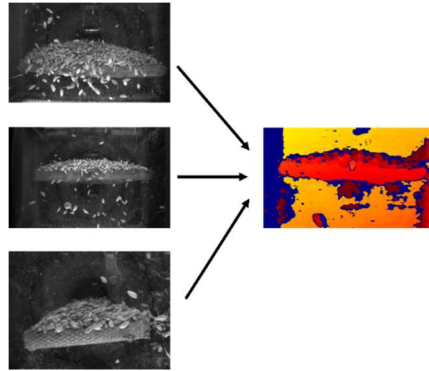
According to the pinhole imaging principle, the mapping from coordinates in the camera coordinate system to image points is linear. However, due to manufacturing errors and the lens's effect on light propagation, this mapping is actually nonlinear, resulting in radial and tangential distortion in the camera. The distortion in the images can be corrected by obtaining distortion parameters through camera calibration and then applying undistortion processing to the original images. In this study, the planar checkerboard method was used for camera calibration, with 20 images of the checkerboard pattern captured from different angles for calibration, as shown in Figure 4. After undistorting the images, the camera's internal parameters  $f_x, f_y, c_x, c_y$  and distortion parameters  $k_1, k_2, k_3, p_1, p_2$  were obtained.



**Figure 4.** Undistortion Using the Planar Checkerboard Method

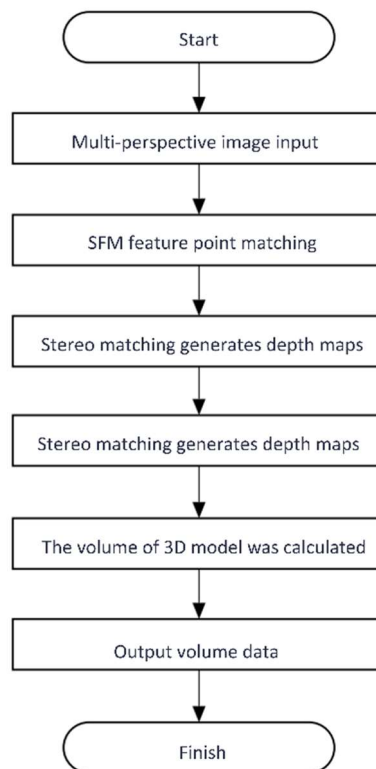
There are two approaches to achieving multi-view 3D reconstruction using a monocular camera. One method involves fixing the 3D reconstruction target object and capturing images of the object from different angles to achieve stereo matching. The other method employs multiple cameras to capture the object from various perspectives to achieve 3D reconstruction. In this study, the target objects are the scraper and the grain piled above it, which are in motion; therefore, method two is chosen for multi-view image capture. Multiple cameras are arranged on the scraper elevator to collect images for feature point detection. The Structure from Motion (SfM) algorithm is used to extract and match features to determine the camera poses from different angles, resulting in a rotation matrix

$R$  and a translation vector  $t$ . After performing stereo matching on the RGB images captured from multiple views, depth information of the images can be obtained. The camera's internal parameters, camera poses, depth information, and RGB images are used as inputs to the improved TSDF lightweight multi-view 3D reconstruction network to construct the 3D model of the grain accumulation. The processing of grain images from different perspectives is shown in Figure 5.



**Figure 5.** Depth Image Obtained from Stereo Matching

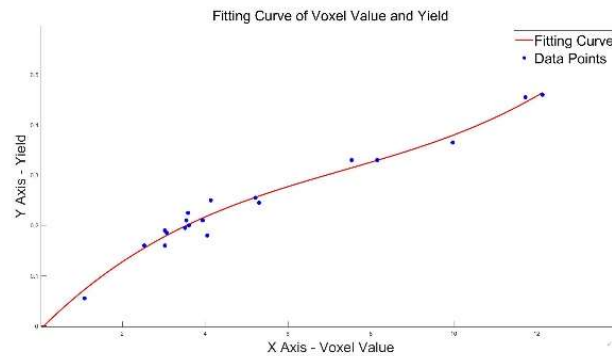
Although the TSDF algorithm offers real-time performance, the reconstruction range of the scene is limited by the fixed size of the pre-defined 3D grid used to fuse depth maps. To further reduce the implementation time for 3D reconstruction, this study investigates both the number of voxel blocks updated and the speed of updates. First, a viewing frustum is constructed based on the camera pose to filter out voxel blocks that fall outside the camera's field of view, thereby reducing the number of voxel blocks updated. Second, an incremental update algorithm is employed to enhance the speed of updating the attributes of the voxel blocks. The process flowchart is shown in Figure 6.



**Figure 6.** Flowchart

### 3. Results

Experiments were conducted to validate the visual monitoring sensor developed in this study. The measured voxel data was fitted with yield data, resulting in a coefficient of determination  $R^2$  of 0.925, indicating that the visual yield monitoring sensor developed in this study is capable of detecting grain flow.



**Figure 7.** Fitted Curve

## 4. Conclusion

The visual yield monitoring sensor developed in this study demonstrates significant potential for accurately detecting grain flow during the harvesting process. By utilizing multi-view stereo reconstruction techniques and image processing, the sensor provides a reliable method for measuring grain accumulation. The strong correlation observed between the measured voxel data and yield data, with a coefficient of determination  $R^2=0.925$ , indicates that the sensor can effectively capture the dynamics of grain flow. This innovation not only contributes to improved yield monitoring in precision agriculture but also optimizes combine harvester performance by providing real-time data for better decision-making.

## References

- [1] Hu Junwan, Luo Xiwen, Ruan Huan, et al. Design of a Dual-Plate Differential Impulse Grain Flow Sensor. Transactions of the Chinese Society of Agricultural Machinery, 2009, 40(04): 69-72.
- [2] Zhang Huili. Research on Online Real-Time Measurement Methods for Grain Flow During Combine Harvesting. China Agricultural University, 2002.
- [3] Zhang Xiaochao, Hu Xiaoan, Zhang Aiguo, et al. A Weighing Method for Yield Measurement in Combine Harvesters. Transactions of the Chinese Society of Agricultural Engineering, 2010, 26(03): 125-129.
- [4] Yang Gang, Lei Junbo, Liu Chengliang, et al. Development of a High-Precision Grain Measurement System Based on Line Structured Light and Machine Vision. Transactions of the Chinese Society of Agricultural Engineering, 2019, 35(08): 21-28.
- [5] Jiang Xin, Yin Wenqing, Pu Hao, et al. A Measurement Method for Grain Volume in Spiral Conveyors Based on Structured Light 3D Vision. Journal of Nanjing Agricultural University, 2019, 42(02): 373-381.