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STUDY ON VISUAL INSPECTION MECHANISM AND DYNAMIC MODELING OF COAL BUNKER

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ABSTRACT

In order to analyze theory and method of coal level detection by intelligent camera, firstly, mathematic model of coal level detection in bunker was established by three-dimensional imaging and synthesis and decomposition of vision signal, which is based on Faugerast's calibration method, and the variation law between image signal and coal level variation in bunker were obtained by theory analysis. Secondly, the experimental simulation system for coal level detection in variation induced by the variation of image signal was constructed, and the image signal variation law was revealed. The numerical simulation model of the coal level detection in vision display was established, the simulation show that the greater the peak and contour points of coal level are, the faster the variation of image signal is, and the greater the initial value of coal level is, the higher the image signal is, and the coal level may have lightly pit. Finally, the image reconstruction shows that the theoretical analysis, experimental research and numerical results are consistent.

Keywords: *3D Image- Forming Principle，The Coal Level Detection In Vision，Image Display，Image Reconstruction*

1. INTRODUCTION

Video action analysis earns its great interest from many potential applications. In video mining area, there have been recently a number of systems developed to extract meaningful semantics from image and video contents. Those we can see the demonstration in the video Google [1], and the landmark structure is in Chum [2], and landmark three-dimension reconstruction is in Snavely [3].

In this paper, we present a framework for matching actions in video, which can be used as a core module for development of a complete visual-based action analysis engine. A typical coal level action can be decomposed into two main stage, feature extraction and learning. Generally, the literature on feature extractions can be grouped into two main approaches, one detail with global features for the coal edge of interest [4]-[6], while the other works on sparse set of local feature, significant results have been obtained in these works. In this work, we approach video action analysis using improved Faugerast's calibration method [7]-[10], and aim to learn not only their local characteristics but also the global shape properties [11]-[13]. In section 2, we presented the developed algorithm that using image processing and three-dimensional (3D) vision techniques to measure the coal level based on the virtual instrument [14]-[16]. Our learning algorithm is able to capture both local and global properties in a simple manner. It also very flexible and can easily accommodate different sets of local action representations. According to a real-time image sampling, we can obtain the practical position information on account of pixels in coal bucker. On the basis of image-forming principle of camera, we can acquire the actual coordinate about the coal level. Finally, in line with the relationship between tangent circles, the coal level in bucker can be measured. This method's aim is to propose a simple, low-cost, running stability [17], easy operation and simply maintenance reaching industrial performances. This paper presents the developments and the experimental results obtained with the method.

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The remaining of this paper will be as followed, in Section 2; we give the theory of coal level detection from vision sensor. Mathematic model of coal level detection is established in section 3. Section 4 will integrate those action model elements into a dynamic structure. At the end of section 4, Experimental results are presented; follow which concluding remarks are given in section 5. By analyzing experimental results on different types of actions, we can then draw some useful conclusion about the improved algorithm and their potential field of application.

2. THE THEORY OF COAL LEVEL DETECTION

The imaging model of vision sensor is a mathematical description of the physical process that is the projection from space scene to 2d imaging plane. According to the imaging forming principle, in figure 1, the point P(x_1, y_1, z_1)in the Cartesian space of vision sensor and corresponding imaging point P (μ, v) inner parameters corresponding relations as follows:

$$\begin{bmatrix} \mu \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} k_x & 0 & \mu_0 \\ 0 & k_y & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1/z_1 \\ y_1/z_1 \\ 1 \end{bmatrix} = M_{in} \begin{bmatrix} x_1/z_1 \\ y_1/z_1 \\ 1 \end{bmatrix} \quad (1)$$

The corresponding relation between parameters is:

$$\begin{bmatrix} x_c \\ y_c \\ z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R & p \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_\omega \\ y_\omega \\ z_\omega \\ 1 \end{bmatrix} = M_\omega \begin{bmatrix} x_\omega \\ y_\omega \\ z_\omega \\ 1 \end{bmatrix} \quad (2)$$

It is hypothesis scenery that the points in the world coordinate system are known, following the laws of reflection, we have:

$$z_c \begin{bmatrix} \mu \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} k_x & 0 & \mu_0 & 0 \\ 0 & k_y & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & p \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_\omega \\ y_\omega \\ z_\omega \\ 1 \end{bmatrix} = M_{in} M_\omega \begin{bmatrix} x_\omega \\ y_\omega \\ z_\omega \\ 1 \end{bmatrix} \quad (3)$$

Here M_{in} denote the internal parameter matrix that is decided by the sensors itself optical and geometrical properties and describe the relation between scene points and image points. (x_c, y_c, z_c) is the scenery coordinate in camera coordinate system, $(x_\omega, y_\omega, z_\omega)$ is the scenery coordinate in world coordinate system, R and p constitute external parameters of sensor that is the M_ω, which describe the positional relation between sensor coordinate system and the three-dimensional coordinate system.

The image sensor in this paper we used three are used to self-calibration by holes imaging principle. In the calculation of the sensor internal and external parameters, at the same time, we can calculate space position information of coal level in coal bunker.

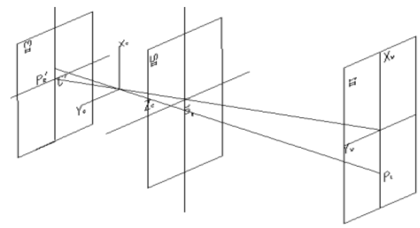

Fig. 1 Pin-Hole Imaging

3. THE MATHEMATIC MODEL AND ANALYSIS OF COAL LEVEL

The improved mathematical model using three visual probes and three visual probes in the same space can make adaptive control from each other, and establish three-dimensional coordinate system circled in O as well, which is the center of a circle in coal bunker bottom, combining with two-dimensional system based on the holes imaging principle. Respectively, calibration visual sensors position is$(x_1, y_1, z_1), (x_2, y_2, z_2), (x_3, y_3, z_3)$. To coal pile vertex P$(a, b, c)$as an example, the sensor to the point P have distance for radius, three round intersection position is the point P, as the equation (4) shows:

$$\begin{cases} (x_1 - a)^2 + (y_1 - a)^2 + (z_1 - a)^2 = r^2 \\ (x_2 - a)^2 + (y_2 - a)^2 + (z_2 - a)^2 = r^2 \\ (x_3 - a)^2 + (y_3 - a)^2 + (z_3 - a)^2 = r^2 \end{cases} \quad (4)$$

In the coal level changing process, visual probe's position is fixed, in order to simplify the conversion formula' s derive, we make the following hypothesis about coal bunker:

(1). Coal bunker bottom as the standard circle, ignore wall irregular form of coal bunker to make visual probe in the standard coordinate system.

(2). It is the hypothesis that image edge profile is clear. In the image processing, we use Laplace algorithm to make the influence of the image burr reduce to minimum.

So it has been a new simple coal level algorithm as follow,

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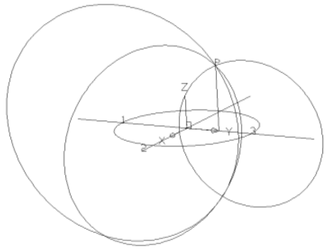


Fig. 2 The geometric relation of three intersections

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} (x_1-x_2) & (y_1-y_2) & (z_1-z_2) \\ (x_2-x_3) & (y_2-y_3) & (z_2-z_3) \\ (x_1-x_3) & (y_1-y_3) & (z_1-z_3) \end{bmatrix}^{-1} \begin{bmatrix} (x_1^2-x_2^2)+(y_1^2-y_2^2)+(z_1^2-z_2^2)+(r_1^2-r_2^2) \\ (x_2^2-x_3^2)+(y_2^2-y_3^2)+(z_2^2-z_3^2)+(r_2^2-r_3^2) \\ (x_1^2-x_3^2)+(y_1^2-y_3^2)+(z_1^2-z_3^2)+(r_1^2-r_3^2) \end{bmatrix}$$

$$K = \begin{bmatrix} (x_1-x_2) & (y_1-y_2) & (z_1-z_2) \\ (x_2-x_3) & (y_2-y_3) & (z_2-z_3) \\ (x_1-x_3) & (y_1-y_3) & (z_1-z_3) \end{bmatrix} \qquad (5)$$

$$R = \begin{bmatrix} (x_1^2-x_2^2)+(y_1^2-y_2^2)+(z_1^2-z_2^2)+(r_1^2-r_2^2) \\ (x_2^2-x_3^2)+(y_2^2-y_3^2)+(z_2^2-z_3^2)+(r_2^2-r_3^2) \\ (x_1^2-x_3^2)+(y_1^2-y_3^2)+(z_1^2-z_3^2)+(r_1^2-r_3^2) \end{bmatrix} \qquad (6)$$

In the image collected process, we calculate the value of K and R and change pixel coordinate system into the actual coordinate system by virtual instrument, thus, we can obtain the specific value of the vertex P in actual two-dimensional coordinate, (a, b) . Then substituting three visual sensors coordinate values to get the actual value of vertex P in the Z axis.

4. EXPERIMENTAL RESULT

4.1 Experimental Project

In order to effectively eliminate the blind spot area a sensor caused and improve the accuracy of three-dimensional data simulation, as shown in figure 3, the distance between every two visual sensors are 90° And also in the same horizontal plane.

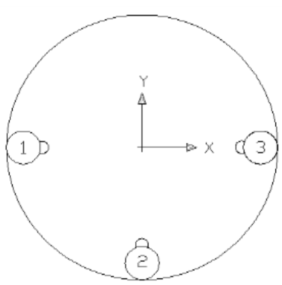


Fig. 3 The Installation Method Of The Three Intelligent Cameras

In the simulation experiments, in order to observe the actual situation in the coal bunker at the real-time and analysis specific change of the coal level value accurately, we select 4 profile measuring point and 1vertex point from a large number of fixed points, located in the coal pile contour line and the vertices. A simulation experiment platform scheme is shown in figure 4:

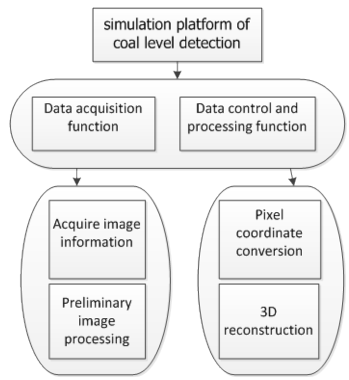
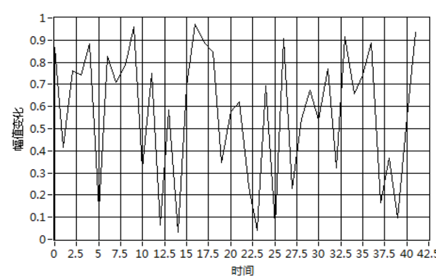
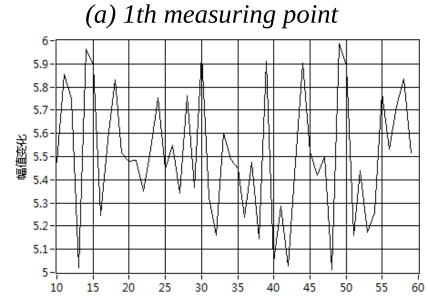


Fig. 4 The Experimental Design

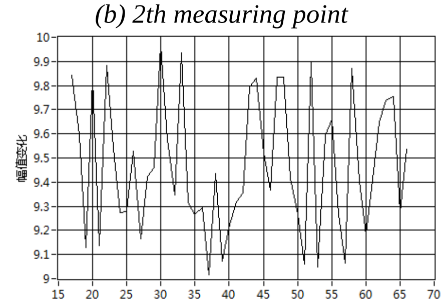
4.2 The Experimental Results and Analysis



(a) 1th measuring point



(b) 2th measuring point



(c) 3th measuring point

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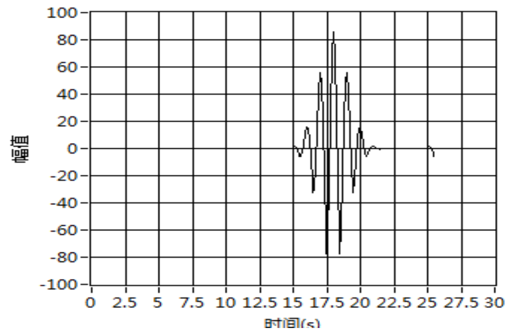

(d) 4th measuring point

Fig. 5 The Curve Graph Of Amplitude Change

Now we select four key positions of the measuring points as an example for details, as is shown in figure 5:

(1). Figure 5(a) indicated that no. 1 measuring point is far from the coal entry. Because the 1 point is far away from the coal entry so that the rate of spread continuously attenuation and coal level have a low change amplitude.

(2). No.2 and no.3 monitoring points are closed to the coal entry. The rate of spread is bigger than no.1 point so that have a higher change amplitude and highest can amount to 6~10cm.

(3).We detected no.4 point display a pulse waveform, this is because the coal level value far from the coal entry increase slowly in the storage process. However, propagation velocity is not decay at the coal entry point so that the changing of coal level has a sharp increase. Therefore, no.4 measuring point produced a similar pulse waveform.

(4). Because of different change amplitude and the rate of coal level change is not uniformity, between no.1 and no.2 points and no.2 and no.3 points appeared different degree of sag area.

5. NUMERICAL-CALCULATION RESULTS OF COAL POSITION DETECTION

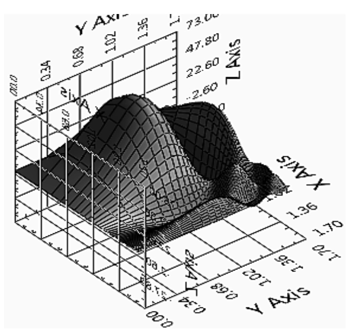

Fig. 6 3D Artificial Hologram

In order to simulate coal level changing process in coal bunker effectively, according to initial status data, the simulation of physical model can divide into three areas named smooth area, sag area, prominent area. The initial condition is as follows：

For visual sensor, H=143.53cm, R=276.34cm. H is the installation height of visual sensor. R is a horizontal distance between visual sensor and simulation coal bunker.

This paper use the improved coal level measurement algorithm, according to the experimental result, we found the change of coal level are not uniformity. Therefore, we selected 9 key points from a large number of measuring data in three divided area, as is shown in table 1, and reconstruction three dimension image by the application of virtual instrument's three-dimension simulation platform.

Table 1 The Value Of Sampling Points

X(pixel)	Y (pixel)	Real height	measurement	error
344	130	20.76	20.7614	0.0014
488	132	21.21	21.1532	0.0567
418	130	21.32	21.3214	0.0014
342	134	21.34	21.3414	0.0014
412	132	23.50	23.4793	0.0206
394	344	54.81	54.8100	0.0001
484	366	55.72	55.7221	0.0021
342	380	60.52	60.5325	0.0125
408	810	129.14	129.1244	0.0155

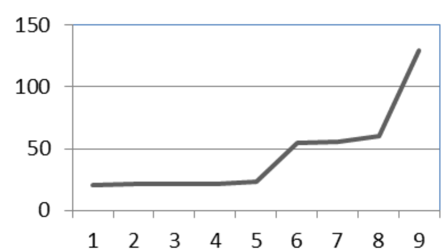

Fig. 7 The Tendency Chart Of Value Change

By contrast with table 1, figure 6 and figure 7, we can be conclude that the value of no.1 to no.4 points didn't change, the value of no.5 to no.6 and no.7 to no.8 points increased slowly, however, no.8 to no.9 have a sharp increase. It described the coal level increasing trend of whole coal bunker from outside to inside, and described the changing process of coal level accurately. The vertex of the coal pile is fastest than others, each outer contour line is along with the increase of radius in turn. But because the slope between

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no.5 to no.6 and no.7 to no.8 are obviously different, no.6 to no.7 have a sunken place. The inhomogeneity decline of material in coal bunker lead to the numerical calculation increased in-consistency caused the different slope between the measuring points. And contrast with the three-dimensional simulation show that a specific height calculation and prediction is consistent, and the method is simple and accurate to ensure a real-time monitoring.

6. CONCLUSION

(1) Through the theoretical analysis to establish a new type of coal detection mathematical model, we can conclude specific position information and the changing trend of the rate of coal level and the quality of calculation data is small so that a real-time detection is possible.

(2) According to deeply analysis of the image signal, we found the bigger the coal pile vertex and contour point of the initial amplitude is, the greater the image of the initial waveform amplitude is and the higher the coal pile vertex and contour points change amplitude is, the bigger the pulse waveform amplitude of the image is.

(3) Given the initial condition in the numerical calculation, the numerical results also show that the bigger the coal pile vertex and contour point change amplitude value is, the greater the slope the display and the steep the image waveform is, the higher the initial amplitude and vertex and contour point of the height are.

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