SIMULATION ANALYSIS AND CONSTRUCTION OF MAIZE SEEDER MODEL BASED ON EDEM (EM SOLUTIONS EDEM)
/
基于 EDEM 的玉米排种器模型构建与仿真分析

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ABSTRACT
In order to improve the large-scale production efficiency of corn and realize the intellectualization and automation of corn seed metering technology, it is necessary to combine modern computer technology with intelligent algorithm to establish a feasible model suitable for corn seed metering device. In this paper, watershed algorithm and EDEM (EM Solutions EDEM) algorithm are used to establish an efficient corn particle recognition model. Watershed algorithm is used for image matching and recognition, EDEM algorithm is used for simulation and processing of corn particles. Twenty corn seeds were selected, and the proportion and volume fraction of seeds with different shapes were calculated by using the model. The parameters needed for simulation were calibrated to verify the reliability of corn sowing accuracy. Through the credibility evaluation of RTM (Resin Transfer Moulding) model in maize seed metering model, it can be seen that the model has credibility, and the variance test result P = 0.662 > 0.10 shows that the credibility of the model meets the requirements. The results show that the model can be applied to the large-scale production of corn seed metering device, greatly improve the production efficiency, has high reliability, and is worthy of practical application and promotion. In this paper, the model construction and Simulation of corn planter based on EDEM are deeply studied and analysed, and the related processes are improved, so as to comprehensively improve the work efficiency of corn planter and improve the quality of planter.

摘要
为了提高玉米规模化的生产效率，实现玉米排种技术的智能化和自动化，需要基于现代计算机技术和智能算法结合，构建出可以应用于玉米排种器的可行模型。此次选取 Watershed 算法及 EDEM (EM Solutions EDEM)算法来构建一个高效的玉米颗粒识别模型，通过 Watershed 算法进行图像的匹配和识别，利用 EDEM 算法进行玉米颗粒的模拟和处理操作。选取 20 粒玉米种子，利用该模型对玉米种子进行不同形状种子的比例及体积分数的计算，对模拟所需要的各项参数进行试验标定，并对玉米种排种的精度进行可信性检验。通过 RTM (Resin Transfer Moulding) 模型对玉米种子排种模型的可信性评估可以看出，该模型具有可信性方差齐性检验结果为 P=0.662>0.10，说明该模型的可信性满足要求。研究显示，此次提出的模型能够应用于玉米规模化的排种生产之中，能够极大提升生产效率，具有很高的可靠度，值得进行生产实践应用和推广。本文对基于 EDEM 的玉米播种机模型构建与仿真进行了深入的研究与分析，并对相关流程进行了改进，以全面提高玉米播种机的工作效率，提高播种机的质量。

INTRODUCTION
At present, China has a large area of corn planting, the planting area and yield of corn has ranked second in the world, and the planting area and yield are increasing year by year. In China, corn is widely used and the social demand is strong, so the stability and high yield of corn planting must be guaranteed to ensure the stable supply of domestic grain *(Gultyaeva E., Shaydayuk E., Gannibal P., 2021).* Based on the analysis of various technologies in current corn planting and production, although the quality of seeds and subsequent cultivation stages will directly affect the final yield of corn planting, the most critical factor in these planting stages is the quality of seed row *(Wang G.P. et al., 2018).* With the development of agricultural industrialization, various kinds of planting techniques are born.

Corn seeding is no longer the traditional manual seeding, but more mechanized equipment such as corn seeder, to carry out more efficient seeding operations. Therefore, the rationality of the design of corn seeder is directly related to the quality of corn seeder *(Dong J., 2018).* Excellent corn seeding machinery can achieve confidential seeding *(Cheng R. and Jin Y., 2018)*. It can ensure that seed row amount, spacing between seeds and planting depth of seeds are in an optimal state at all times and ensure the growth and development space of each seed to the maximum extent, thus usable areas of land are used to the maximum extent *(Wang B. et al., 2020)*. Only in this way can the yield per unit area reach the maximum and the yield of corn crop can be increased across the board *(Gross G. and Hoffmann A., 2018; Martínez-Moreno F. et al., 2021)*. At the same time, with the addition of corn seeding machinery, manual labour is greatly released and the efficiency of corn seeding is increased exponentially, making large-scale corn planting and centralized and unified management possible. However, due to the special seasonality of corn planting, the research cycle of corn seeder becomes longer and its research work is more difficult *(Kang D., 2018)*.

Although a large number of excellent research results have been achieved and corn seeder has been improved for several generations after its development to date, the research on the model construction and simulation of EDEM-based corn seeder is still in a short period of time, and there are still many deficiencies *(Nouiri M. et al., 2018)*. With the increase of social demand for the quality of corn seeding, how to prompt the quality and efficiency of corn seeding is an urgent matter. Only by further research on the corn seeding device, can the basic needs of the public be fundamentally satisfied *(Wu M.Y. et al., 2018)*. Therefore, the EDEM-based model construction and simulation of corn seeder are deeply studied and analysed, and relevant processes are improved to comprehensively improve the working efficiency of corn seeder and improve the quality of seeder *(Lan Y. et al., 2021)*.

Watershed algorithm and EDEM technology are used to create a corn seed row model by taking the corn seed row problem as an example. Watershed algorithm is a data operation algorithm that uses iterative random sampling to extract and filter abnormal data to obtain the mathematical model. The algorithm needs to acquire necessary image data information first, such as the edge of the object and the gray level information. The accuracy of these two information acquisition will directly affect the accuracy of detection *(Tai J J et al., 2020)*. According to the different fields used, it can be divided into two types; one is spatial processing and frequency domain processing *(Wei W et al., 2021)*. The former is directly processed on the image itself, the latter is to carry out various calculation and analysis on the image after special processing. EDEM technology mainly includes pre-processor, solver and post-processor. The main functions of the preprocessor are to set up analytical geometry model, cut and analyse grid elements and nodes, set element types and material parameters, set and analyse boundary conditions, etc *(Jensen R., 2021)*. The solver reads the result file of the preprocessor and the numerical method is used to solve the answer according to the input conditions. The post-processor will process a large amount of data into interface graphics in a regular way and make analysis animation, so that the analysis data result is convenient for the user to interpret the answer. Watershed algorithm and EDEM technology are the mainstream trend in maize seeding in the future *(Fan et al., 2021)*.

Aspects of innovation are as follows: 1) EDEM is used to build and simulate the model of corn seeder, and targeted structural optimization is carried out according to the simulated seeding data in reality. Simulation model is established by combining with different parameters such as rotational speed and air pressure. (2) RTM model is used to evaluate the credibility of maize seed seeding model, and the actual effect of theoretical model is verified by real data.

The structure is as follows: the first section mainly describes the research background and the organizational structure. The second section mainly describes the research status of Watershed algorithm and EDEM technology in the corn seeder. The third section mainly describes the design process of the algorithm model. The fourth section mainly describes the practical experimental research of maize seed - discharging model. The fifth section mainly summarizes the research results.

MATERIALS AND METHODS

Watershed algorithm

Watershed algorithm is a data operation method that uses iterative random sampling to extract and filter abnormal data to obtain the mathematical model. Watershed algorithm is mostly applied to image processing in engineering (as shown in figure 1). The basic implementation process is as follows:

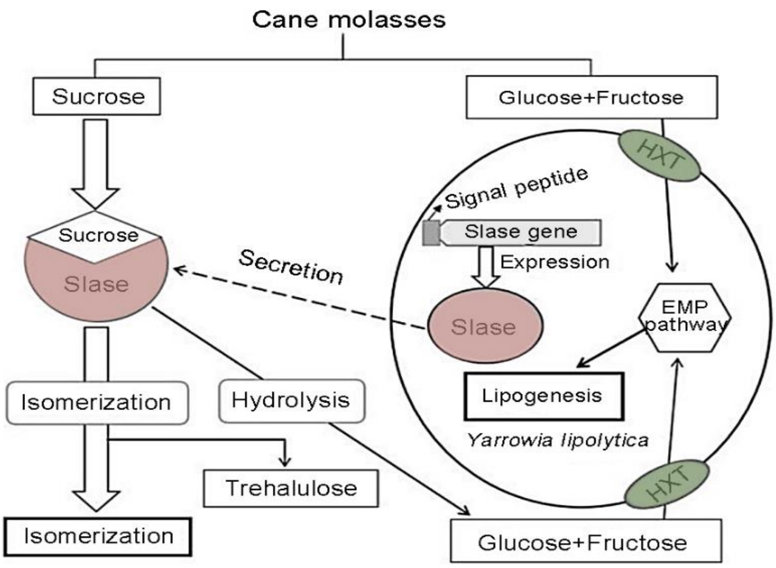

Fig. 1 - Watershed algorithm is mostly applied to image processing in engineering

Necessary image data information, such as object edge and gray level information should be acquired. The accuracy of these two information acquisition will directly affect the accuracy of detection. According to the different fields used, it can be divided into two types. One is spatial processing and frequency domain processing. The former is directly processed on the image itself, the latter is to carry out various calculation and analysis on the image after special processing. The spatial processing formula is as follows:

$$g(x,y) = EH[f(x,y)] \tag{1}$$

Where $f(\cdot)$ is the image before enhancement. $g(\cdot)$ is the image after enhancement, and EH represents the enhancement operation. The edge information of the image can directly reflect the shape of the object, and its importance is self-evident. It can project most of the information of the item only by the local image information. However, there are many difficulties in its acquisition. The data obtained by the edge in the system is presented as discontinuous gray value, which requires special algorithm to calculate its edge (as shown in figure 4). It is usually calculated using the first and second derivatives. The gradient corresponds to the first derivative, and the gradient operator is the first derivative operator. For a continuous function $f(x,y)$, its gradient at the position (x,y) can be expressed as:

$$\nabla f(x,y) = G(x,y) = \left[G_x \, G_y\right]^T = \left[\frac{\partial f}{\partial x} \; \frac{\partial f}{\partial y}\right]^T \tag{2}$$

Generally, in order to reduce the amount of calculation, the absolute value approximate gradient amplitude is used to calculate.

$$|G(x,y)| = |G_x| + |G_y| \tag{3}$$

Then corner point extraction is carried out for the image content which has been preliminarily processed. Suppose there is a variable I_x and a variable I_y to represent the first partial derivative of the graph I in two different ways, the Cartesian axis of x and the axis of y. Then the function $w(x,y)$ can be used to represent the two-dimensional Gaussian smooth function in Cartesian coordinates. The calculation process of this function is shown in the following two formulas.

$$M = \sum_{x,y} w(x,y) \tag{4}$$

$$R = \det M - k \cdot (traceM)^2, k = 0.04 \sim 0.2 \tag{5}$$

The specific number of each corner point R on the image can be obtained by solving formula (5). Then the corner points calculated by the normalization method are matched to obtain the value of the corner points. The matching calculation equation is shown as follows:

$$\frac{\partial(H_z u)}{\partial t}+\frac{\partial(uH_z u)}{\partial x}+\frac{\partial(vH_z u)}{\partial y}+\frac{\partial(\Omega H_z u)}{\partial s}-fH_z v=$$
$$-\frac{H_z}{\rho_0}\frac{\partial p}{\partial x}-H_z g\frac{\partial \eta}{\partial x}-\frac{\partial}{\partial s}\left(\overline{uw}-\frac{v}{H_z}\frac{\partial u}{\partial s}\right)-\frac{\partial\left(H_z S_{xx}\right)}{\partial x}-\frac{\partial\left(H_z S_{xy}\right)}{\partial y}+\frac{\partial S_{px}}{\partial s} \tag{6}$$

$$\frac{\partial(H_z C)}{\partial t}+\frac{\partial(uH_z C)}{\partial x}+\frac{\partial(vH_z C)}{\partial y}+\frac{\partial(\Omega H_z C)}{\partial s}=-\frac{\partial}{\partial s}\left(\overline{cw}-\frac{v_\theta}{H_z}\frac{\partial C}{\partial s}\right)+C_{source} \tag{7}$$

$$NCC=\frac{\sum_i (I_1(x_i,y_i)-u_1)(I_2(x_i,y_i)-u_2)}{\sqrt{\sum_i (I_1(x_i,y_i)-u_1)^2\sum_i (I_2(x_i,y_i)-u_2)^2}} \tag{8}$$

It is worth noting that the results obtained by using the idea of normalization are often mixed with some singularities. These singularities are the abnormal data that belong to the image corner point values with noise and cannot be described by the mathematical model. Therefore, Watershed algorithm needs to be used to purify the image corner point value, the algorithm is a mathematical morphology segmentation method based on topological theory. The basic idea is to treat the image as a geodesic topological landform. The gray value of each pixel in the image represents the altitude of the point. Each local minimum and its affected area is called a catchment basin, and the boundary of the catchment basin forms a watershed. In the purification process, the image should be considered separately according to the three colour channels of red, green and blue. Thus, the following linear algebraic equation is obtained:

$$\begin{pmatrix} R_2 \\ G_2 \\ B_2 \end{pmatrix}=\begin{pmatrix} c_r & 0 & 0 \\ 0 & c_g & 0 \\ 0 & 0 & c_b \end{pmatrix}\cdot\begin{pmatrix} R_1 \\ G_1 \\ B_1 \end{pmatrix}+\begin{pmatrix} d_r \\ d_g \\ d_b \end{pmatrix} \tag{9}$$

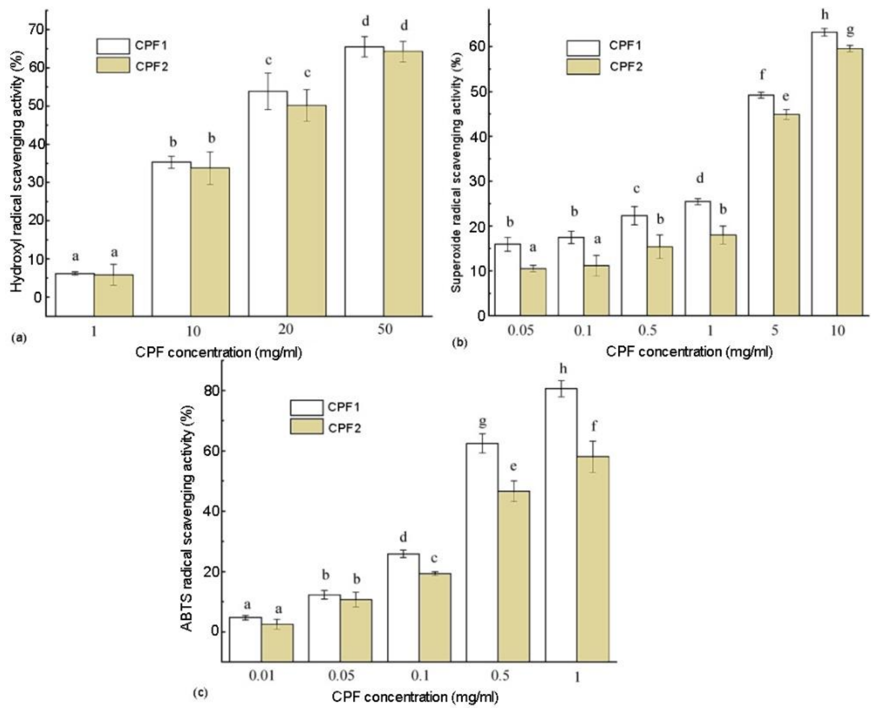

Fig. 2 - In the process of purification, the image should be considered separately according to the red, green and blue colour channels

In the above formula, variable R_2, variable G_2 and variable B_2 respectively represent the red, green and blue colour channels of the image. The variable (c,d) is mainly used to represent the transformation parameters of the linear equation.

The red channel is taken as an example to calculate. First, suppose that there is n group of different image corner point data, and the variable d_n represents the absolute value distance between different data points (R_1,R_2) and line (c,d). At this point, it is purified by iterative summation as shown below:

$$E = \sum T(d_n^{\ 2}) \tag{10}$$

In the above formula, when the condition satisfies $d_n^2 < Thre^2$, then $T(d_n^2) = d_n^2$. And the other way around is $T(d_n^2) = Thre^2$. The corners of the image that meet the requirements are filtered out and the iterative calculation is continued. The whole purification process is completed until there is no significant change in the value. At this time, all data points belong to the data that can be normally described by the mathematical model. Finally, the image needs to be segmented. The effect of image segmentation will directly determine whether the image analysis is in place.

After the image is segmented, the similarity between the image and the established image in the database is calculated and matched according to the calculated results.

The image matching result is extremely its characteristic result. The following functions are used to measure the similarity between T and f:

$$SE(x,y) = \sum_{i=1}^{N}\sum_{j=1}^{N}[f(x-i,y-j)-T(i,j)]^2 \tag{11}$$

In the above formula, the matching degree between image T and sub-image f at the (x,y) coordinate is provided.

Matching results can be calculated by expanding the above formula:

$$SE(x,y) = \sum_{i=1}^{N}\sum_{j=1}^{N} f^2(x-i,y-j) - 2\sum_{i=1}^{N}\sum_{j=1}^{N} f(x-i,y-j)T(i,j) + \sum_{i=1}^{N}\sum_{j=1}^{N} T^2(i,j) \tag{12}$$

$$\frac{\partial(H_z u)}{\partial t} + \frac{\partial(uH_z u)}{\partial x} + \frac{\partial(vH_z u)}{\partial y} + \frac{\partial(\Omega H_z u)}{\partial s} - fH_z v = -\frac{H_z}{\rho_0}\frac{\partial p}{\partial x} - H_z g\frac{\partial \eta}{\partial x} - \frac{\partial}{\partial s}\left(\overline{uw} - \frac{v}{H_z}\frac{\partial u}{\partial s}\right) - \frac{\partial\left(H_z S_{xx}\right)}{\partial x} - \frac{\partial\left(H_z S_{xy}\right)}{\partial y} + \frac{\partial S_{px}}{\partial s} \tag{13}$$

$$\frac{Dk}{Dt} = P_k + \frac{\partial}{\partial x_j}\left(\left(v + \frac{v_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right) \tag{14}$$

EDEM technology

EDEM is the world's most professional simulation and analysis of particle processing operation of the standard computer-aided engineering analysis software. The visual modeling of the particle processing process can help designers to complete the processing of different bulk materials. CAE (Computer-aided engineering) is an innovative research and application technology for industrial design and production technology development in addition to computer-aided design CAD (Computer-aided design) and computer-aided manufacturing CAM (Computer-aided manufacturing). It is an auxiliary research technology that assists in the creation, design, modification, analysis and optimization of design by making use of the powerful computing functions of computer.

The introduction of CAE technology makes the related research and industry personnel on the computer possible. Results are predicted and verified by the computer analysis of the original design CAD geometric model and combined with various physical problems analysis technology and operations to reduce the cost of loss caused by the test errors. It can shorten product design and development schedules, and points out the design by scientific data analysis results and potential risks and problems in the process of production; CAE design application benefits include the following : (1) design changes that assist in optimization, (2) assist in the understanding and elimination of problems, (3) rapidly accumulate application knowledge, systematize data and establish design criteria (as shown in figure 3).

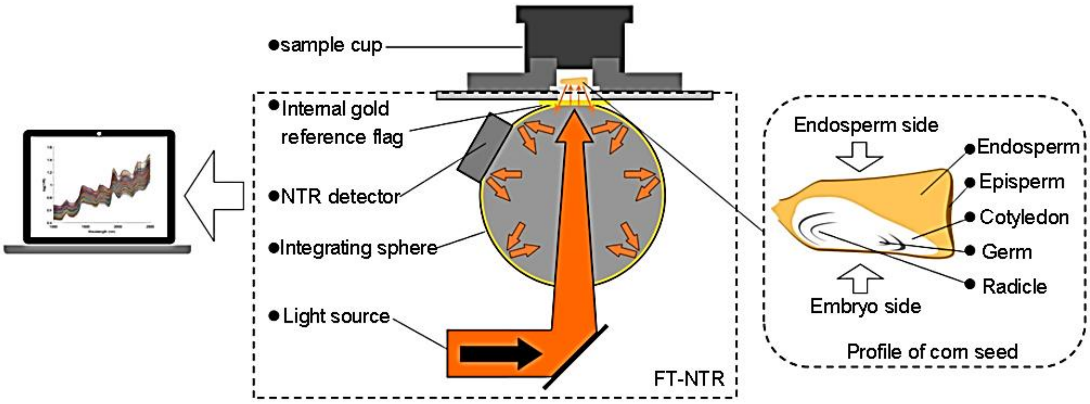

Fig. 3 - Multicast is the sending of data packets to a host group represented by a unique IP address

At present, in engineering application, relatively mature CAE technology fields include: structure analysis, sound field analysis, vibration analysis, optical design analysis, fluid analysis, heat transfer analysis, electromagnetic analysis, mechanism motion analysis and plastic injection moulding mould flow analysis, etc. The development of engineering design CAE has been quite mature in practicality, reliability and computational efficiency, and has a fairly basic theory of analysis and accurate analysis results. CAE analysis software includes two categories: generic and proprietary. General CAE software provides a wide range of selectivity and software expansion application scope, but the software system is usually large, easy to consume a lot of computer resources. It is difficult to operate due to the lack of targeted use, and different general software has its own advantages and characteristics. Special-purpose analysis software provides the most professional results in specific engineering fields. The software system is small, the system resources required for calculation are less, and the practical application and operation are simpler (as shown in figure 4).

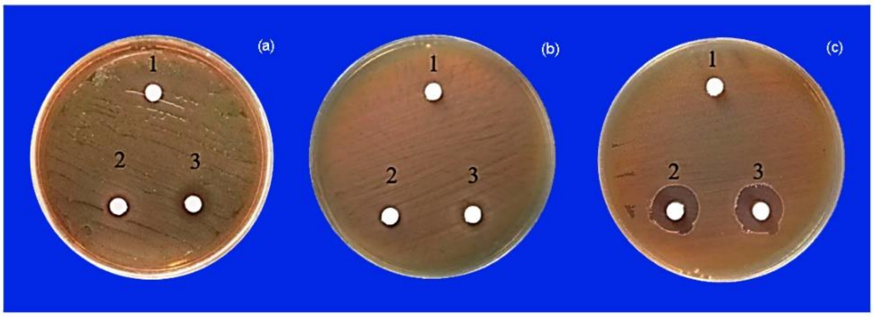

Fig. 4 - The independent Mrouter is responsible for multiple propagation

The industrial application of CAE analysis software are already quite mature, and other kinds of special software, verification through constantly update analysis parameters, thus the reliability of the software applications is enhanced. The product development design process is greatly shortened by combining with computer-aided design CAD and powerful computer aided manufacturing engineering CAM, thus trustworthiness is increased. For industrial application and development, CAE has advantages of cost reduction, high speed and quality. Through the accumulation of continuously updated application material database, CAE simulation analysis results are closer to the real situation. In combination with the efficient solution algorithm that has been gradually improved in recent years, the calculation efficiency and accuracy are growing exponentially. This also lays a more indispensable link for CAE in engineering development and application. In terms of calculation technology, CAE analysis technology uses approximate numerical methods to calculate and solve, instead by the traditional mathematical solution method. Numerical methods can solve many problems that cannot be solved correctly in pure mathematics, and its application level is more extensive.

RESULTS

Experiment overview

Watershed algorithm and EDEM technology are used to create a corn seed row model by taking the corn seed row problem as an example.

First, buy corn seeds of different varieties (3-5 varieties) and classify them by shape (trapezoid, four-pyramid, and spheroid) to determine the proportion or volume fraction of seeds of various shapes. The size of three axes is measured, and the shape of different seeds with a large proportion is scanned by 3d scanner, and the particle model is established. The parameters needed for simulation (static friction coefficient, rolling friction coefficient, collision recovery coefficient) are tested and calibrated. Required parameters are obtained; routine testing of corn seeds (accumulation Angle, resting Angle, etc.) is done; then, RTM model is used to verify the credibility of maize seed scheduling model (as shown in figure 5).

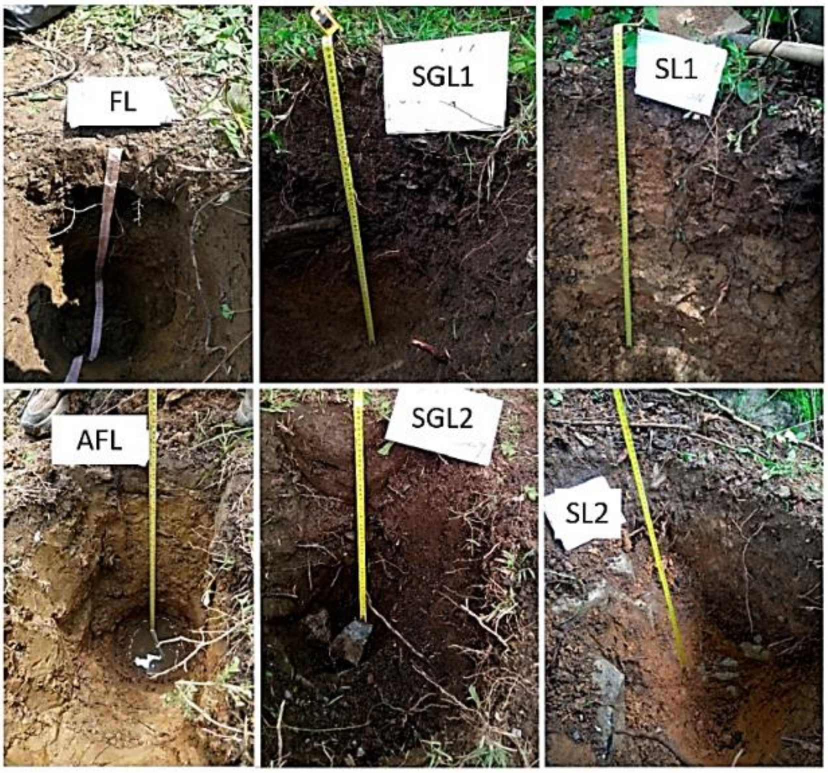

Fig. 5 - The expert model of building energy intelligent management is applied to the energy management of the building garden

Experimental process

The test equipment mainly uses the seed adsorption needle grinded and processed by the injection needle of adsorption, and installs on the seed arranging machine in the way of vertical adsorption. The seed adsorption needle of different specifications can be replaced according to the need. The cursor calliper made by Japanese Mitutoyo Company is used to measure the geometric characteristics of seeds with the measuring range of 0-50mm and precision up to 0.05mm. The electronic balance produced by Japanese AND（ Android）company is used to measure the average distribution of seed quality AND to establish the parameters of seed physical characteristics. The MPS 2.3 Series LED（Light Emitting Diode） Digital Pressure Sensor v3rc-g-m produced by CONVUM Company is used to manually set the high and low Pressure parameter values. The high Pressure is mainly used to determine whether the adsorption needle has absorbed the seeds, and the low Pressure is used for reserve. Parameter setting mode: vacuum suction value not adsorbed to seeds < high pressure parameter value in the sensor < vacuum suction value adsorbed to seeds. Judgment mode: when the vacuum suction value of the adsorption needle is higher than the high pressure parameter value in the sensor, the seed is adsorbed. The pressure range is -100 kPa ~ 0 kPa, and the reaction time is below 1msec. Vacuum voltage valve can be used to fine adjust the size of the vacuum suction to avoid the influence of too much or too little vacuum suction adsorption force. The vacuum filter can prevent the dirty things or seeds from accidentally running into the pipeline in the seeding operation. It can filter in the filter to avoid pipeline obstruction. FX2N-48MR Mitsubishi programmable controller is used. Output/input (Y/X) contacts have 24 points with FX2N-1PG uniaxial NC module controlling servo motor.

The FX2N-232BD communication substrate produced by twin image Company is connected with the RS232 through jumper to enable the computer to communicate with PLC（Programmable Logic Controller）. The experimental materials are mainly purchased from the seedlings planted by ordinary farmers.

They are mainly spherical corn seeds and flat corn seeds, respectively. 128 lattices of round seedling tray are used with a pore diameter of 4.2cm and a depth of 3.5cm.

Experimental steps: (1) measure the length and diameter of spherical corn seeds, the thickness and length and axle diameter of flat corn seeds, and record them. After measuring 20 corn seeds, take their average length. (2) Before starting the experiment, machine vacuum MPS 2.3 Series of LED Digital Pressure Sensor V3Rc - G - M operates for a period of time, let the vacuum suction tend to be stable. And then Pressure Sensor of high Pressure parameter value is adjusted. The parameter value ranges from the vacuum suction value not adsorbed to the seed < the high pressure parameter value within the sensor < the vacuum suction value adsorbed into seed, so as to ensure that the misjudgement of the computer monitoring system and avoid no seed metering. (3) The man-machine interface statistics and operation of the computer monitoring system are recorded. The error between the control and manual operation statistics after each experiment is analysed and discussed by using EDEM technology. (4) The 128-cell-acupoint disc is used as the experimental material, and different parameter factors are changed as follows: 1) different seeds: spherical corn seeds and flat corn seeds, respectively, affect seed arrangement accuracy. 2) Seed adsorption needles of different types: the numbers are 22, 23, 24 and 25, respectively. 3.) Different oscillation degrees: 1.5, 2.0 and 2.5, respectively. 4) Rotation times of rotary cylinder: once, twice and three times, which affect the precision of seed arrangement. 5) Repeat each experiment 3 times.

The experimental results are shown in figure 6 below:

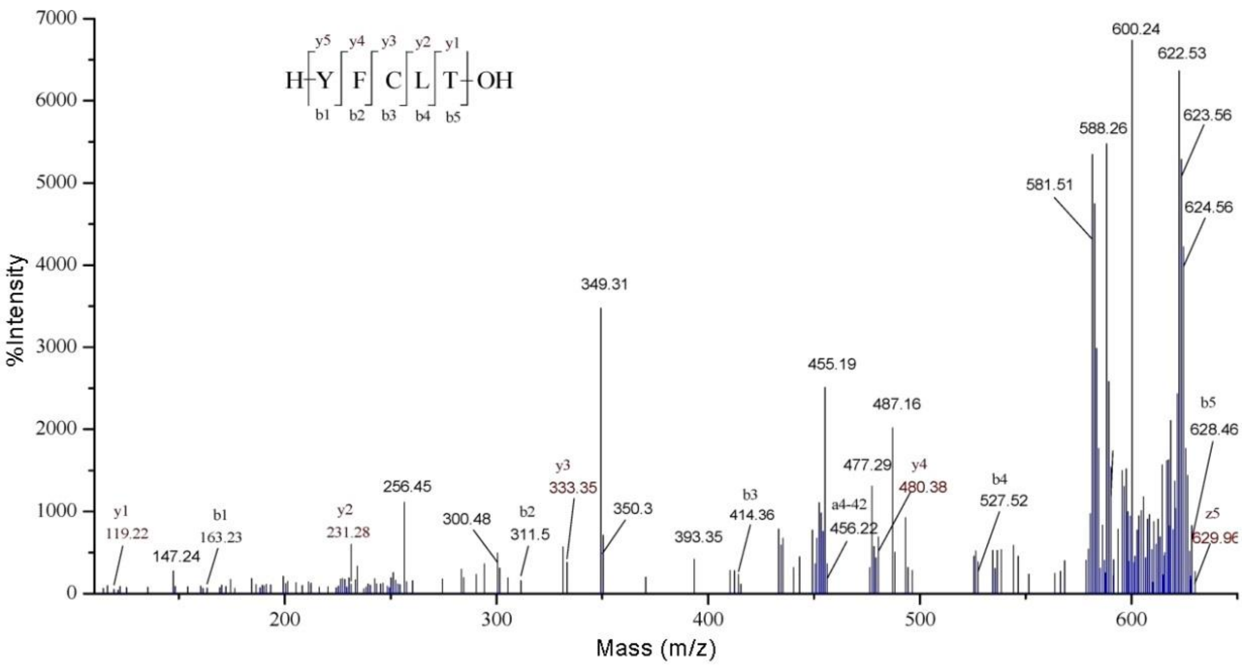

Fig. 6 - Actively issue abnormal energy consumption and alert to reduce wrong energy consumption

Experimental evaluation

After the experiment, RTM model is used to evaluate the credibility of maize seed seeding model. The steps are as follows: Find out the different evaluation indexes of the evaluated object and establish an evaluation weight matrix R, calculate the product of each row element of the judgment matrix R, and get the actual weight values of the different indexes of the evaluated object. Then, calculate the evaluation score by computing the weight values and evaluation content data. The evaluation results can be obtained by calculating the data information recorded in the experiment in accordance with the above calculation method (as shown in figure 7).

The data in the figure shows that the test result of homogeneity of variance for the credibility of the maize seed row model designed is $P=0.662>0.10$. Since the result is much larger than 0.10, it can be inferred that the credibility of the maize seed row model has reached the requirements.

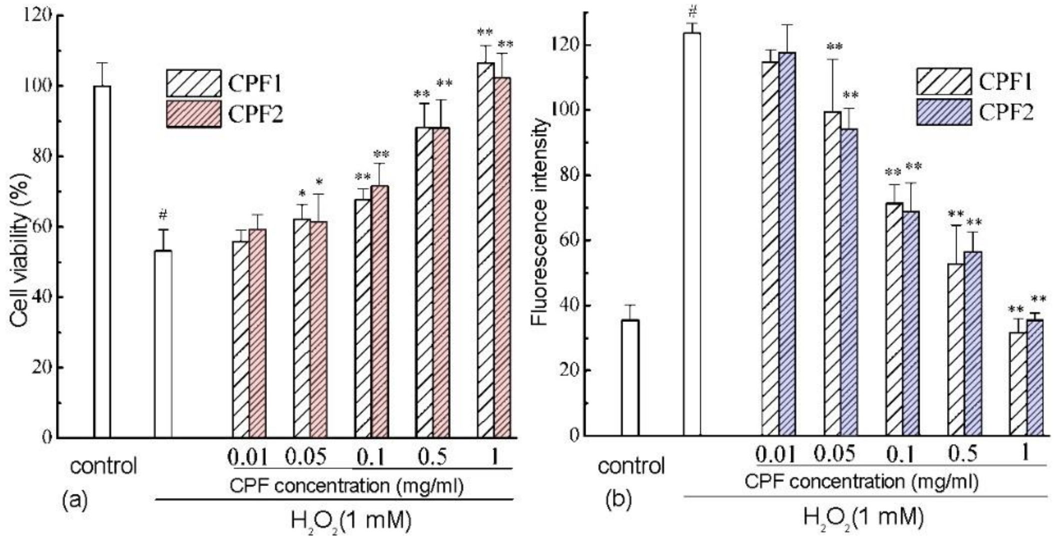

Fig. 7 - Precision instrument of watt-hour meter tester with fault in transmission system

CONCLUSION

The watershed and EDEM algorithm were used to solve the corn seed row problem. First of all, buy different varieties (3-5 varieties) of corn seeds, according to the shape (trapezoid, pyramid, sphere) classification, determine the proportion or volume fraction of various shapes of seeds. The size of three axes was measured, and the shape of different seeds was scanned by a three-dimensional scanner. The length and diameter of spherical corn seeds were measured by vernier calliper, and the thickness, length and shaft diameter of flat corn seeds were recorded. After measuring 20 pieces, take the average length. Before the start of the experiment, turn on the vacuum mps2.3 series LED digital pressure sensor v3rc-g-m of the planter for a period of time, stabilize the vacuum suction, and adjust the high-pressure parameters in the pressure sensor. The statistics and calculation of man-machine interface of computer monitoring system are recorded. By using EDEM technology, the error of statistical calculation is compared with that of manual calculation at the end of each experiment. 128 grid tray was used to change the influence of different parameters on the precision of corn seed metering. At the end of the experiment, RTM model was used to evaluate the reliability of maize seed sowing model. The evaluation data showed that the homogeneity of variance test result of the credibility of the designed maize seed row model was $p = 0.662 > 0.10$. As the result is much larger than 0.10, it can be inferred that the credibility of maize seed row model meets the requirements. However, there are some defects in the designed structure of corn seeder, which is not conducive to the popularization and application of this method. In addition, there are some conclusions error in the selection of seed quantity or due to the insufficient quantity. Therefore, the structure of top part of corn sowing will be improved in the future. The pattern selection of seeds will adopt more cardinality. The deficiencies in this area will be improved in future studies.

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