Developing of the System for the Filling Layer Simulation

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Abstract

The paper is devoted to the issue of the simulation system development to model filling layer of granulated material. The tools for the filling layer simulation with particular force to green ore pellets are the utmost important for mining processing plants. The software suits implemented for system realization are described. The main features and options of the application are reviewed. The algorithm for the filling layer model formation is adduced. The results of the test show that the model of the granulated material reflects the real physical object with high accuracy so it can be used for its further investigation.

1 Introduction

One of the principal characteristic in production and processing of the non-coherent material fraction is its distribution over size grade. Grain-size distribution assessment of the crushed, granulated or pelletized particles of non-coherent material is significantly important for mining processing plants to control their technological process. In particular, grain-size distribution of the green ore pellets is main characteristic of their quality. At the moment it is paid close attention to the problem of green pellets geometry measuring [1-8]. Analysis of the bibliography shows that the advanced way to measure this criterion belongs to the machine vision systems. This approach allows on-line controlling of the material grain-size distribution in the workflow. Camera captures images of the top leaf of the granulated material. Then the isolation of each visible particle and its linear size and volume measurement are implemented with help of digital image processing methods. The main part of any contactless measurement system based on machine vision is an image processing and analysis unit which includes an algorithm for the isolation and detection of granulated particles.

It is necessary to estimate the tolerance of the computation unit while developing and integration of such system. In order to evaluate the precise of the algorithm's grain-size distribution the screen analysis of the of the green ore pellets test sample should be implemented [10, 11]. However, such a test of validity of computational data over against experiment is highly laborious and time-consuming. Moreover, the correctness of the algorithm should be tested over the huge amount of the top leaf images with the given distribution law of the non-coherent material particles. Also it is preferably to have an opportunity to form images with arbitrary distribution law. That is why the simulation system for modelling of the filling layer of spherical granulated particles is likely to be developed. Such a system will allow to form images of the green pellets with target values of their grain-size distribution. The result of the modeling will be applied in computation unit checkout and validation, performance and accuracy comparison of the different algorithms devoted to granulated particles measurement.

2 Development of the Simulation System

Modern equipment and software allow to create a physical model of the huge amount of particles interaction with high accuracy and realistic behavior. There are a number of companies who offer software and hardware to simulate complicated physical processes. For example, GDI provides ROCKY software for 3D analysis of behavior of the non-coherent material particles [12]; Pasimodo solution by Inpartik company is suitable for granular medium modeling [13]. Despite the wide latitude of these software packs they are not appropriate for development of the algorithms for machine vision systems as they have no tools to simulate displacement , quantity or type of lighting sources in the scene.

The developed system is based on the PhysX middleware by NVidia which used in modern games and graphic editors. Implementation of these middleware gave an opportunity to create effective framework for filling layer simulation which combines high computation performance and accuracy of the geometry and physical compositions. Interface DirectX is implemented to visualize simulation process. It is specified by the high image processing speed due to v video adapter hardware acceleration. DirectX is one of the most popular tool for the graphics application development. Combining PhysX and DirectX allows to compute the interaction of modeling objects with high accuracy and display the results of the simulation in a clear view.

2.1 Principal features of the system

Simulation system has a wide range of input parameters which influence the simulating process. System operates with conditional units so user determines the specific system of units for the parameters of the structure elements while simulation. It is necessary to set the specific probability laws for distribution of the position and object size in each instance of the simulation to obtain the most adequate model. For example, the position of the spherical particle in X-axis direction could be set according to the uniform density

$$f(x) = \begin{cases} \dfrac{1}{b_x - a_x}, & x \in [a_x, b_x] \\ 0, & x \notin [a_x, b_x] \end{cases} \quad (1)$$

where $[a_x, b_x]$ – variation interval of X coordinate, or the normal density

$$f(x) = \frac{1}{\sigma_x \sqrt{2\pi}} e^{-\frac{(x-\mu_x)^2}{2\sigma^2}} \quad (2)$$

where μ_x – mean value, σ_x – dispersion of X coordinate distribution. It is similar to Y coordinate.

The size of the generated spheres is set in conditional units of their diameters which can also be generated according to the uniform, normal or even arbitrarily density. In the latter case the density of the diameter or gran-size distribution is made as histogram of categorization. The developed system allows to create up to 9 categories. Within each category the size of the sphere is set by normal density.

It is extremely important zone in machine vision system to arrange for the artificial lighting of the measuring in order to develop effective algorithm for the isolation and detection of granulated particles. The developed software provide for tools to configure the scene lighting. It assumes generating of the lighting sources and definition of their parameters. Lights are also significant in the visualization of the filling layer simulation. They give an opportunity to set the required contrast of the image, configure shadows and regulate luminance differences on the edge between the visible particles of the filling layer. It is possible to generate up to 8 light sources. Each light is regulated by its position relative to the scene. The light can modulate one of three types of the light flux: spot light, point light and directional light.

The result of the simulation is 3D scene of the location of the model mass of the spherical granulated particles in respect to the static container. The images of observed scene are of the 768*576 pixels and .bmp format.

2.2 Model formation algorithm

The filling layer model construction is carried out as following.

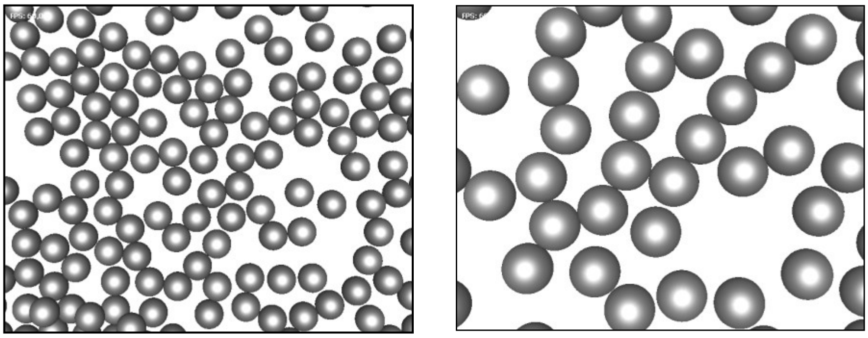
1. Initialization. Initialization of the model means creation of the external environment – scene. It involves the parameters required for simulation , environment settings and all objects which could be added to the model. What is more, PhysX middleware and DirectX interface are also initialized while creation of the scene. It includes setting the initial parameters and operation mode.
2. Object creation. Each object in the system is described by two features: actor and shape. The former includes whole range of the physical characteristics that are necessary to simulate behavior of the object: size, density and interaction forces. The latter is a representation of the object in the scene. The visual representation of the object is created in parallel with the object itself and used through the whole simulation cycle.
3. The location of the object is set by two components: coordinates of the center of mass and the attitude quaternion which describe the body rotation around the given 3D vector by the specific angle. Objects are generated in the system throughout the simulation cycle.
4. Simulation time-step calculation. Simulation time-step is one of the most significant parameter that has an effect on the model creation accuracy. The frequently used time-step is 1/25 second.
5. Simulation. At this stage PhysX calculates objects' collisions within given amount of time and outputs their coordinates by the end of the time-step.
6. Visualization. The shape of the each object is displayed by the DirectX interface. The location of the camera and influence of the lighting sources are calculated while visualization process.
7. Model destruction. Stages 2-5 are repeated until the model will be stopped. After that all objects are deallocated. System is ready to the new simulation cycle.

3 Results of the Modeling

Two auxiliary experiments were conducted in order to validate the system. Images of the monolayer of the particles were generated (Fig. 1) with adjusting coefficient of 5 pix/mm.

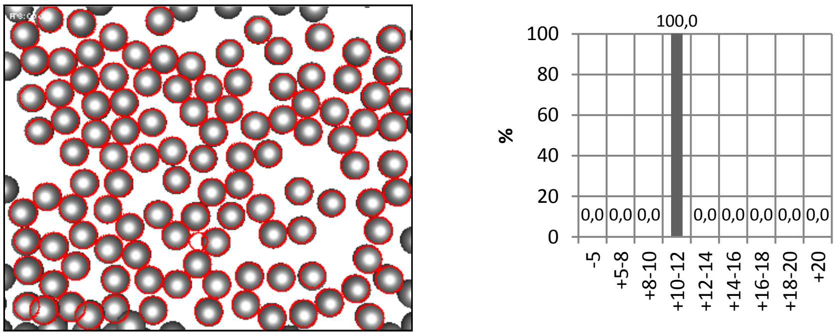
Validity of sphere generating on the images was checked manually and by software-analytic approach. An amount of totally visible spheres is 108 in Fig. 1a and 27 in Fig. 1b. The manual measurement of the spheres' sizes was implemented with help of Paint graphic editor over 70 spheres from Fig. 1a and 27 spheres from Fig. 1b. The results confirmed the accuracy of the sphere generating. In order to fulfill the latter validation approach the algorithm for measuring geometry of the granulated or pelletized particles in the filling layer was programmed [9]. Algorithm output is presented in Fig. 2-3.

One object in Fig. 2a isolated incorrectly, however, its volume is quite small and the extent of an error is acceptable. There are two detection incidents (at the edge of the frame) in Fig. 3a. Absolute error in this case is 1.7% due to the small amount of the spheres in the image.



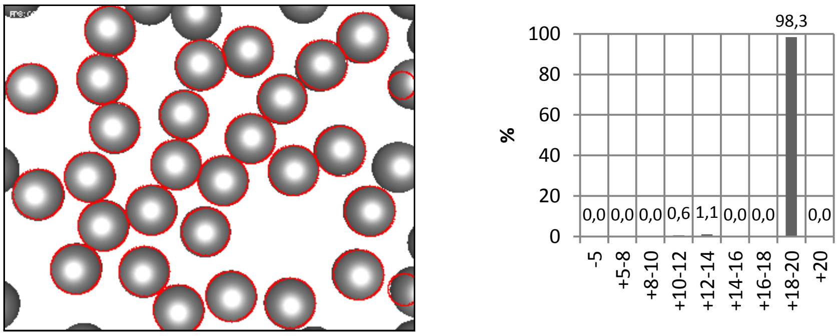
a) b)

Figure 1: Images of the monolayer of the spherical particle of the different size: a – 11 mm, b – 19 mm



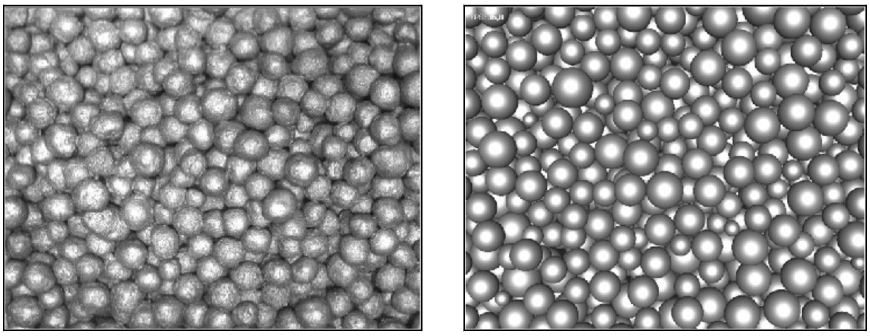
a) b)

Figure 2: Sphere isolation algorithm output for spheres of the 11 mm in diameter: a – display of the isolated spheres; b – distribution histogram



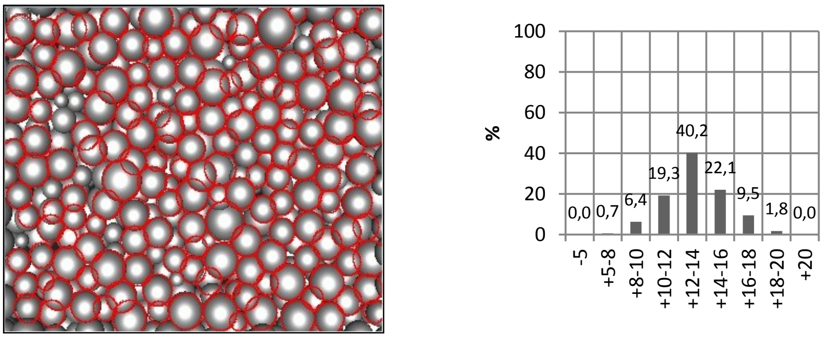
a) b)

Figure 3: Sphere isolation algorithm output for spheres of the 19 mm in diameter: a – display of the isolated spheres; b – distribution histogram



a) b)

Figure 4: Image of the sample of green ore pellets (a) and simulated filling layer of the spherical particles with the same grain-size distribution



a) b)

Figure 5: Output of the algorithm for the isolation and detection of spherical particles with given distribution law: a- display of isolated spheres; b- distribution histogram

In order to validate the generation of the filling layer of the spherical particles by the arbitrarily density the sample of the green ore pellets were taken [10]. Image of this sample is presented in Fig. 4a. The results of the screen analysis [11] of the sample are in the Table 1.

Table 1: Grain-size distribution in the sample of green ore pellets

Category, mm	- 5	+5-8	+8-10	+10-12	+12-14
Category mass percentage , %	0	0,2	3,9	24,7	39,9
Category, mm	+14-16	+16-18	+18-20	+20	
Category mass percentage , %	26,8	4,5	0	0	

Obtained data on green ore pellet diameter distribution were input in modeling system as initial conditions. Image of the filling layer simulated by the arbitrary density law introduced in Fig. 4b. This image was processed by algorithm for particles geometry measurement [9]. Output of the algorithm is presented in Fig. 5.

Obtained results show that:

- Mean absolute error of the grain-size distribution of the simulated filling layer of the spherical particles is 2.88% over all categories.
- Margin of absolute error in main category of the simulated particles (+ 12mm-14mm) is 0.3%.

4 Conclusion

Developed simulation system allows to create models of the filling layer of spherical particles with arbitrary characteristics of grain-size distribution as well as display the results of the simulation. This tool is applicable to validating algorithms for grain-size distribution measurement. Moreover, the developed software provides definition of the spatial features of the non-coherent material. According to the result of the simulation, the model of the filling layer reflects the real physical processes of the filling layer formation with high accuracy and could be applied for its further investigation. In particular simulation results could be applied for experimental check of such properties of the simulated structure as fractional void volume, closeness of packing, etc. Fractional void volume is a significant indicator for measurement of the gas permeability of the green ore pellets that is argue problem for mining processing plants. Developing of such system gives the balance of advantage. Firstly, it is an optimization of the gas flow rate required for the roasting. Secondly, it is a reduction in expenses for production tests and laboratory data analysis of incoming pellet flow. Finally, it is an opportunity to forecast the roasted pellets quality.

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