ALGORITHM FOR GRANULAR MATERIAL FLOW RECOGNITION USING VISUAL DATA

Edgars Rudzroga
Latvia University of Agriculture
edgars.rudzroga@gmail.com

Abstract. In the article an algorithm for granular material flow recognition is proposed. The algorithm consists of four main steps – grain selection, grain tracking, searching for flows and grain reselecting. During the first step grains for tracking are selected. After the tracking information is acquired, it is analyzed to detect flows. The main task in flow detection is to find a certain amount of neighbouring grains that are moving in the same direction and the travel distance long enough to be considered a flow. Minimal grain count that composes flow and minimal travel distance should be configurable, because they affect how fine or large flows are detected. After certain time periods new grains for tracking must be selected. By using this algorithm the flow direction and velocity can be detected. The algorithm can be used to monitor and analyze granular material flows in processes like grain drying. This is a general algorithm for granular material recognition and for more specific applications some changes and improvements may have to be applied.

Keywords: flow recognition, multiple object tracking.

Introduction

Computing with images is no more just for science and research, but it is used in all kinds of real life applications in fields of astronomy, medicine, robotics etc. As research in this field has increased, tasks which before could only be done by humans due to computer inability to understand the image content, now can be done by machines. Surveillance and object tracking can be considered as such tasks. Although there is much research done in object tracking and over the years many algorithms for it have been developed [1-4], there is little research done in the field of flow detection which is composed by many objects moving in the same direction.

The purpose of the research was to develop the algorithm which could be used for the flow direction and velocity detection. This algorithm can be useful in processes like grain drying or any other applications involving granular material flow, where it could be used for monitoring purposes or to collect data for analysis.

Materials and methods

In order to develop algorithm for granular material flow recognition a physical model was manufactured. The physical model was manufactured in resemblance with a gutter in grain dryers and grain was used as the granular material for creating flows. In order to develop the algorithm, correlations between grains that make flows and problems which could occur during the recognition process were sought by observing and analyzing grain flows in the physical model. Flows with various directions and velocity (from 0.001 to 0.05 $m \cdot s^{-1}$) were created and observed during the experiments. Also, principles of object tracking and target tracking systems [5] were studied and analyzed. During the experiments HD web camera with 1600 x 1200 sensor resolution and 30 frames per second digital video capture speed was used as an optical device. The camera was placed about 20 cm above the physical model. After the algorithm was developed it was implemented in Windows application.

At first we must define what is meant by granular materials and granular material flow. Granular materials are all kinds of materials which have a granular form, for example, all kinds of grains – wheat, barley, rye etc. Further in this article the term grain will be used instead of the granular material, because this algorithm is mainly intended for grain flow recognition. The granular material flow is composed by grains which are relatively near each other and are moving in the same direction with the same velocity. In Figure 1 you can see three granular material flows. The first flow is composed by grains which are moving from the top of the image to bottom before they reach the obstacle. After the grains have reached the obstacle they split into two separate flows.

As you can see in Figure 2, the algorithm for granular flow recognition consists of four steps – grain selection, grain tracking, searching for flows and grain selecting. After grain selecting the algorithm does not end but returns to the grain tracking step and this loop continues as long as the flow recognition is required.

Fig. 1. **Granular material flows**

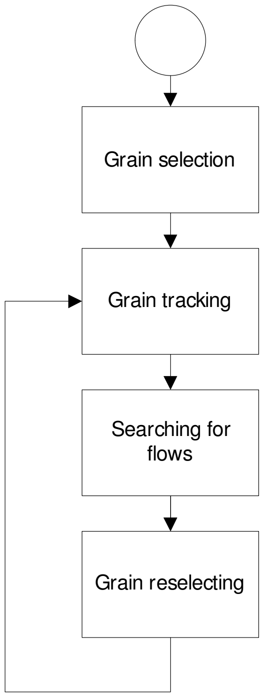

Fig. 2. **Algorithm for granular flow recognition**

Results

In order to figure out the most suitable actions for each of the algorithm steps, it was necessary to run experiments by using the physical model in laboratory. The experiments were done in February 2011 and more than twenty experiments were carried out during this time.

Grain selection and tracking for granular flow recognition

In the first step of the algorithm grains for tracking are selected. The flows usually are composed of many grains, so to detect the flow it is not necessary to track all grains in the scene. Theoretically all grains in the scene could be tracked, but practically it would require large computational resources. The grains for tracking are chosen in such a way that the interval between two neighboring grains does not exceed a certain length. The maximum length of the interval should be configurable, because by decreasing the interval length more fine flows can be detected, but also more computational resources are required. Therefore, the user should be able to choose the maximum interval length to balance the requirements for precision and the available computational resources. In Figure 3 you can see a grain selection example.

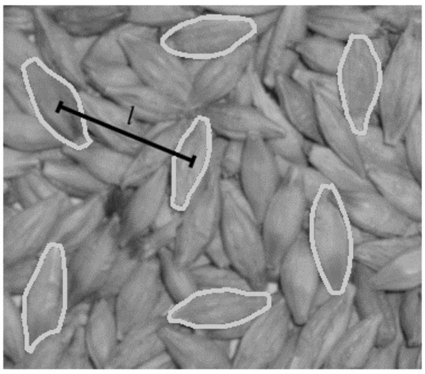

Fig. 3. **Grain selection:** l – distance between two grains

The next step of the algorithm is grain tracking during which the new grain positions are acquired. It is not necessary to track grains after every video frame, but tracking should be done after the same time interval. The length of the interval depends on how fast or slow the flows are in the scene. If the flows in the scene are relatively fast then a shorter time interval should be chosen. The information about grains positions and time in which they were in those positions must be stored, because it is required later in the next algorithm steps for flow searching and flow velocity calculation.

Searching for flows and grain reselecting for granular flow recognition

The next step of the algorithm is searching for flows. The main task is to find the neighboring grains which are moving in the same direction with the same velocity by analyzing the data obtained in the previous step. Flow detecting involves three steps:

- Find moving neighboring grains which are changing their positions, but the distance between them stays constant or within certain amplitude.
- Check if there are enough of these neighboring grains to consider it a flow. The flows are composed by many grains, so if there are only two neighboring grains moving in the same direction, it can not be considered a flow. The minimal grain count for flow should be configurable, because it affects how fine or large flows are detected.
- Check if the distance the grains make is long enough to consider it a flow. Before moving grains can be considered a flow, they have to travel a certain distance. The minimal distance length also should be configurable.

If a flow is detected then it is necessary to store its data. The data include the coordinates and time in which the grains that compose the flow during their movement in flow were in those coordinates and the flow velocity. If there already is a flow with the same coordinate coverage and velocity, then it can be considered as the same flow and it is not necessary to store its data.

The flow direction can be obtained by analyzing grain coordinates as they move through the flow. The flow velocity is average velocity of all grains that compose it. The velocity for each grain is calculated by dividing the distance the grain has made in the flow with the time that was required to make that distance. The distance the grain has made is measured in pixels, so the information about the actual pixel size is required to calculate the real distance. The grain movement velocity can be calculated using the formula:

$$v = \frac{p \times s}{t} \tag{1}$$

where v – grain velocity, $m \cdot s^{-1}$;
p – pixel count;
s – actual pixel size, m;
t – time, s;

Because not all grains in the flow are being tracked, therefore the velocity calculations might be a little erroneous, but this error can not be considered as significant. It should be noted that the fewer the grains compose a flow, the more impact they each have on the flow velocity, so there could be cases when grains with slightly different velocity than other grains in the flow could considerably impact the flow velocity calculation. The flow velocity calculation accuracy is also affected by fact that there is a slight difference between the actual pixel size at the edges and in the middle of the scene. The higher resolution pictures are used, the more this error increases. But this error can be considered as significant only if very high precision results are required. For the best result an optical device should be placed directly above the scene.

The algorithm can be used to recognize flows with practically any reasonable velocity, but it should be noted that its ability to recognize flows with high velocity depends on the optical devices frames per second rate – the higher the flow velocity, the more frames per second are required to recognize the flow. It should also be noted that this algorithm can only be used to recognize flows on the top layer of granular materials.

It is likely that after a certain amount of time in some regions in the scene there will be no grains which are selected for tracking. For example, if there is a flow from the top left corner of the scene to the bottom right corner, then after a while all selected grains from the top left corner will have moved to the bottom right corner or even left the scene like you can see in Figure 4. Due to various circumstances the flow direction or velocity can change, but if there are no selected grains in the top left corner then it will not be possible to detect these changes. Therefore, in regions where there are no selected grains, it is necessary to select new grains for tracking. The new grains for tracking should be selected by using the same principles that are used for grain selecting in the first step of the algorithm – selecting grains within interval.

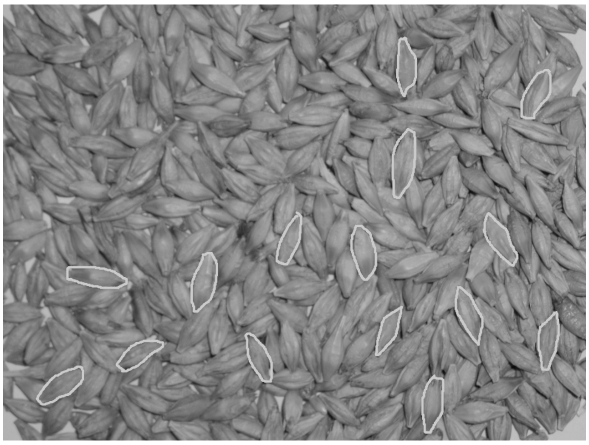

Fig. 4. **Selected grain movement**

Conclusions

In this work an algorithm for granular material flow recognition is proposed which consists of four main steps – grain selection, grain tracking, searching for flows and grain reselecting. The algorithm can be used to detect the flow direction and velocity. The algorithm is relatively simple and designed with the idea that it can be used to do real-time granular material flow recognition. This is a general algorithm for granular flow recognition and for more specific applications some changes and improvements may have to be applied.

Further research should be done in searching for the most appropriate segmentation, object recognition and tracking algorithms for the proposed algorithm implementation. There are problems like occlusion that are associated with object tracking and are not fully resolved by this algorithm. It is also possible that granular material flow recognition can be done better by using a completely different approach.

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