

## NOVEL APPROACH ON OPTICAL ANALYSIS AND MULTICHANNEL SORTING OF GRAIN SAMPLES

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**Abstract** – This paper deals with entire automation of Besatz analysis of grain samples. Thereby a declaration of its mandatory relevance by laboratory request is given and research in image processing by a colour line scan camera as well as development of sorting principle and construction is explained in detail. It is concluded in statement of results and further investigations.

**Keywords:** image processing, object segmentation, food analysis, mechanical sortation, process control

### 1. INTRODCUTION AND MOTIVATION

Identifying the ingredients of a grain shipment (by ship, train or truck) is an important issue to its acceptance. Thereby three main cases are important:

- avoidance of receiving spoiled or toxic (e.g. by mycotoxins) grain,
- necessity of pre-processing steps (e.g. cleaning),
- agreement of salary.

Therewith the decision of the acceptance or refusal of the delivery is made overall. Unfortunately it is not possible to analyse the complete volume of the supply. Instead, taking samples would be expedient. Precise standards for quantities and extraction locality are well defined internationally. One aim is analysing samples very briefly (fewer minutes) to obviate long idle times to suppliers. The sample volume must be as high as possible to achieve a high statistical accuracy.

This procedure called 'Besatz Analysis' is manually performed by skilled laboratory staff [1] screening and sorting the samples. Manual inspection and grading is costly manned, requires much time and is tainted with a grand error ratio. Subsequently the separate grain categories (see Fig. 1) are available for weighting and restoring after visual analysis and hand sorting. Weighting of particular ingredients is requested by legal instructions of the EU [2], [3] and is performed by usual lab methods also manually.



Fig. 1. Typical ingredients of a grain sample.

An automation of this process must fulfil that second step of physical sortation of grain fractions besides the first step

of analysing each object itself, concluding to weight the fractions manually or also automated.

The developed method of analysis is based on image acquisition by a colour line scan camera, which is arranged above a conveyor belt. Image evaluation and object recognition result in two relevant conclusions:

1. Determination of assignment category derived from classification result of each object.
2. Position of objects to trigger sorting control unit for respective class at accurate moment.

### 2. IMAGE ACQUISITION BY THE COLOR LINE SCAN CAMERA

The image acquisition is carried out by the color line scan camera and the conveyor belt with continuous velocity ( $v$ ). There are many different setup principles of the color line scan camera, from which three of them were tested and chosen.

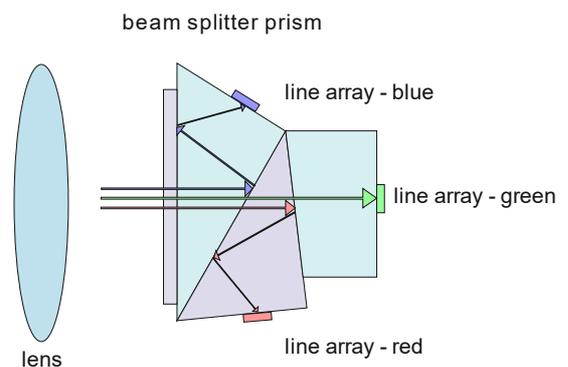


Fig. 2. Beam Beam splitter in a line scan camera with three lines (red, green, blue), each with  $n$ -pixels

While the line image acquisition is possible to be carried out with any kind of movement with the first all-purpose camera type (see Fig. 2), the other two principles (see Fig. 3 and Fig. 4) need a constant linear movement orthogonal to the line direction to generate usable images.

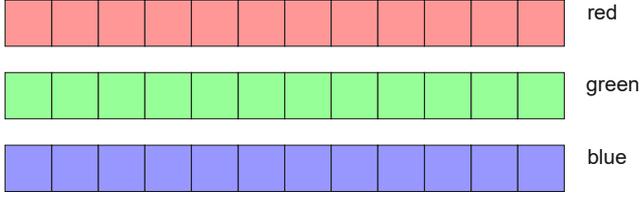


Fig. 3. Color line scan camera with triple line (trilinear) and three times  $n$ -pixels red, green, blue

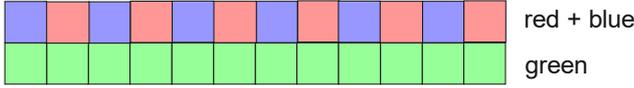


Fig. 4. Color line scan camera with double line (bilinear) and two times  $n$ -pixels red, blue and green

This requirement is fulfilled with the analyzing and sorting of grain because the measured material is located on a belt with a constant velocity orthogonal to the line direction of the camera. The demand on the accuracy of the movement and the camera layout depends on the line distances on the chip.

The smaller these distances, the bigger are the deviations that can be tolerated according to the camera layout and the belt movement. For this reason the producers make an effort for preferably small line distances, what is working out pretty well recently. Additionally it must be mentioned that in comparison to the triple line, an interpolation is necessary for the double line to determine the three color values red, green and blue for every pixel.

Afterwards the reproduction scale has to be determined from the line length  $L_z$  and the width of the object field  $B_o$ .

$$L_z = n_{pix} \cdot b_{pix} \quad (1)$$

$$\beta' = \frac{L_z}{B_o} \quad (2)$$

Now the width  $B_{pix}$  and the length  $L_{pix}$  of the object-pixels can be calculated.

$$B_{pix} = \frac{b_{pix}}{\beta'} \quad (3)$$

The pixel length will be determined by the velocity of the conveyor belt in feed direction. To achieve square pixels, it is necessary that the pixel length in feed direction  $L_{pix}$  per read-out line equals exactly the width of the pixel  $B_{pix}$ .

$$L_{pix} = B_{pix} \quad (4)$$

This will be achieved by the one line period  $t_z$  being exactly equivalent to the time for this distance at the given feed rate of the conveyor belt. The reciprocal value – the line rate  $Z_R$  – can be determined likewise.

With the knowledge of the belt velocity  $v$  follows the duration of the line image  $t_z$  and the line image rate  $Z_R$  as the reciprocal value.

$$t_z = \frac{L_{pix}}{v} \quad (5)$$

$$Z_R = \frac{v}{L_{pix}} \quad (6)$$

Through triggering the camera with impulses lead off the belt velocity  $v$ , it is sure that a change in the belt velocity doesn't affect the geometry of the image.

### 3. IMAGE PROCESSING STEPS

Image acquisition is based on a line scan camera with 4k pixel in RGB colour space and is triggered with conveyor feed motion. As result of synchronisation images with accurate lateral aspect ratio are acquired and stored in local memory of connected computer. Next step is segmentation of separate objects (kernels), which means to cut connected image regions out of entire acquired big image data. Subsequently calculating a feature vector of single object and comparing it to stored features (approx. 200 by shape and colour) of reference objects. Thus each object is assigned to object class with maximum likelihood of correspondence (SVM classification). Unfortunately natural products typically show major inner class variability in addition to minor distinctness of classes [4], [5].

To achieve quite elementary segmentation of objects, a blue coloured belt was chosen (see Fig. 5). Combined with wideband LED illumination (both incident and transmitted light), the background is easily distinguishable from the grain because the spectra of natural products normally are not shortwave (blue coloured).



Fig. 5. Blue colored conveyor belt with grain sample on it acquired by color line scan camera

To be based on that various methods exist to perform proper segmentation. One to be obvious is a comparison of grey value channels:

$$p(x,y) = \begin{cases} 1, & b < (r,g) \\ 0, & otherwise \end{cases} \quad (6)$$

Where  $p(x,y)$  is a pixel in  $x$ -th column and  $y$ -th row of colour area image and  $r, g, b$  is grey value of channel red, green and blue on pixel  $p$ . Here obtaining a binary image with objects (one) and background (null) is realized.

Another method implemented is the determination of suitable threshold from histogram analysis and operating only on single proper grey value channel. Several pre and post processing steps (e.g. smoothing, closing) proof to be reasonable for feasible segmentation results. Following segmentation process classification and position data of each single object is relevant for further sorting.

The classification is realized by using a support vector machine (SVM). The recognition rate is a significant performance characteristic of an image recognition system,

achieving excellent results with the developed prototype. The results, the recognition rates per each object class, are shown in Fig. 6.

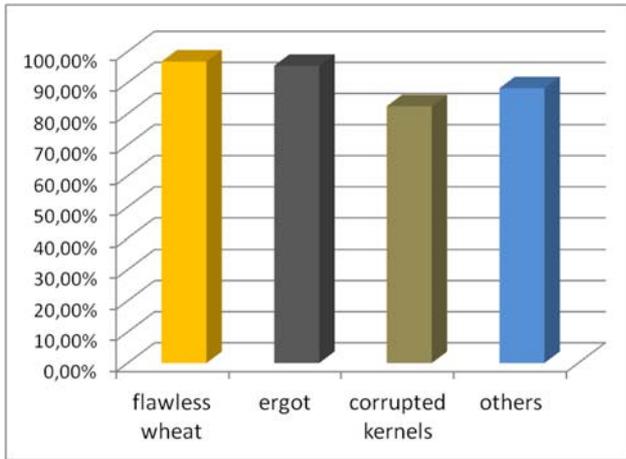


Fig. 6. Reached recognition rates of the four object classes

The total recognition rate  $r$  is calculated as the ratio between the number of all objects correctly classified and the total number of objects (7).

$$r_{\text{total}} = \frac{\text{number of all objects correctly classified}}{\text{total number of objects}} \cdot 100\% \quad (7)$$

The trained SVM reached a total recognition rate of 94% and individual recognition rates range from 82% to 97% for the given dataset, which consists of 4 summarized object classes from different cereal varieties, like flawless wheat, ergot, corrupted kernels and other contaminations.

#### 4. SORTING PROCEDURE

Besides image recognition (segmentation, feature extraction and classification) a second process also starting with object segmentation is necessary: determination of position data of single objects. Segmented objects are irregular expanded and the pixel data is extracted. Binary masks depict a suitable method of purposing position values. Coordinates of gravity centre  $x_s$  and  $y_s$  are calculated from binary objects. Furthermore additional shape criteria (e.g. maximum chord) might be needful to determine. The centre of gravity is linked clearly and distinctively with a single object (kernel) and will be maintained until the sorting process is terminated.

Both information combined together (assignment of class and position of objects) yield to control signals of ejection flaps. Alternatively pneumatic fast shift valves for suction or purging can also be applied. The entire process of object recognition and position determination needs to be completed till single objects reach the sorting range (problem of real-time capability). Caused by congenital characteristics of grain special challenges arise: variable dimension, highly differing shape and mechanical sensitivity of particular ingredients.

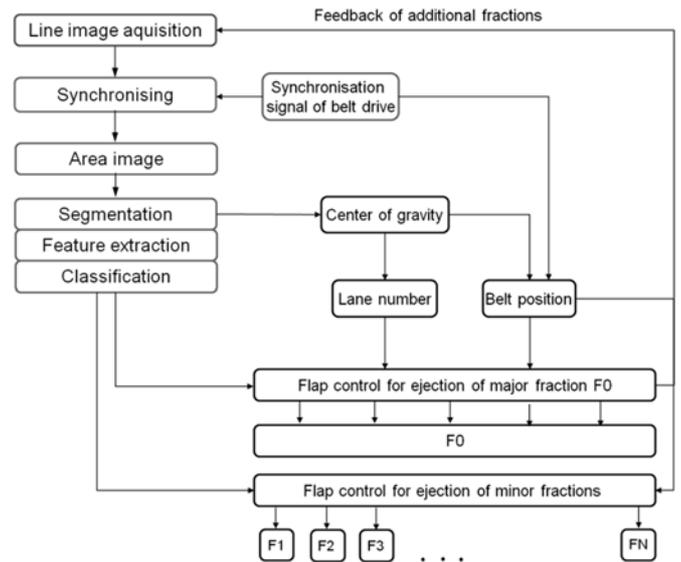


Fig. 7. Workflow of double-stage sorting principle.

The sorting process is performed in two steps to obtain cost-efficiency and prompt separation of grain samples, see Fig. 7. It is a matter of fact that with natural products, a main category (e.g. flawless wheat) often ranks predominant due to total quantity. In the first step of analysing and sorting the major fraction ( $F_0$ ) is separated with higher flow-rate initially. In the second step, the single separation of all remained categories (typically called 'Besatz')  $F_1 \dots F_n$  with distinct less flow is followed. The Sequence of both sorting steps can be designed variably. Manual or automated refeeding of remaining classes into analysing passages already used in here is characteristic. Although an additional discrete unit for analysis could follow up.

#### 5. MECHANICAL STRUCTURE

The structure of the apparatus for double-stage analysis including automated feedback is shown in 8. Patent pending [6].

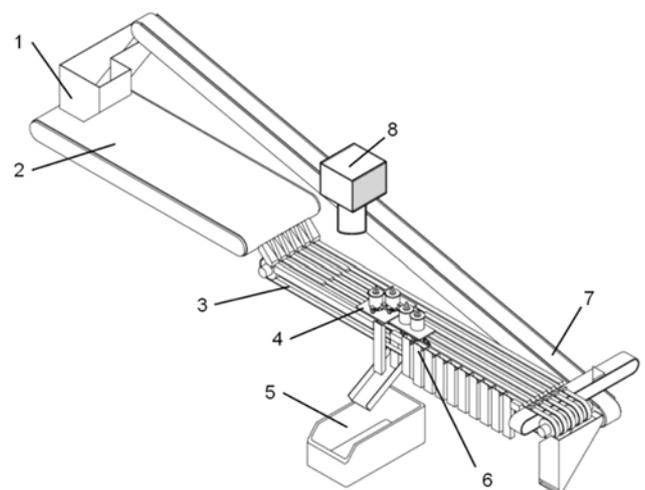


Fig. 8. Equipment configuration of optical analysing and multichannel sorting.

Reservoir 1 provides the supply of the grain sample. Particular kernel end up on the vibrating conveyor 2 separating objects in lateral direction to transport orientation. Five lanes of conveyor 3 are formed, followed by an optical inspection by the line scan camera 8. Therewith the sample flow is quintuple on a major fraction. Single objects reach from the vibration to the belt conveyor in discrete lanes and with more tape speed to separate the grain in longitudinal direction. The colour line camera is mounted above the feed band to investigate all lanes simultaneously. A never-ending area image with square pixel is acquired by synchronisation between line rate and tape speed. In addition to the image recognition position, the determination of the kernel is also performed.

Precise localisation of objects in lateral direction (y-axis) is not required because the objects are moving in separate lanes. Merely the lane numbers (1 to 5) are needful for the ejection control. The longitudinal position to conveying the direction (x-axis) is computed to determine the accurate instant of time in reference to continuous tape speed to trigger respective ejector 4. In the first stage, the main proper class  $F_0$  is ejected collaterally on all five lanes and collected in storage tank 5. *Besatz* is picked up on the belt ending and traced back on feedback 7 exclusively to the first lane. The image detection and classification of the additive fractions  $F_1 \dots F_n$  is followed up. Due to the fact that the first lane is in margin position all remaining classes can be dropped out in succession by the corresponding ejector 6 to the separate containers. Finally all filled reservoirs can be easily weighted manually or automated like requested incipiently.

## 6. CONCLUSIONS

The presented method and device are an adequate solution for an automated *Besatz* analysis. For the first time it combines high-precision object recognition and multichannel physical sorting of grain fractions which are both demanded. The developed apparatus is designed low-cost by two-step procedure (less ejection units) and efficiency (quintuple lanes) to achieve sufficient flow rates of 50g grain per minute. Summarized, it performs essentially more promptly and precisely than a manual inspection and sortation.

## ACKNOWLEDGMENTS

This work is encouraged by funds of BMWi under grant of ZIM (AiF Projekt GmbH, KF 2184730KM3), Germany 2013.

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