Process Monitoring using three dimensional Computed Tomography and Automatic Image Processing

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Abstract. In this paper we present a fast three dimensional computed tomography system in combination with automatic 3d image processing, which gathers necessary information for production control of sugar beet seed. We outline the design of the inspection system and the three dimensional image processing. Within one hour the geometrical parameters of more than 1000 seeds (about 3-4 mm diameter) are measured with accuracy better than 0.1 mm.

Introduction

In the last five years three dimensional computed tomography (3d-CT) is more frequently used in automotive industry for failure analysis and for development of new products. In plastic injection moulding industry 3d-CT is successfully applied to measure geometrical parameters or to characterise the quality of the casting part in combination with automatic 3d image processing [1].

The production of commercial seed requires information about the morphological structure especially in case of sugar beet seed because of the variable anatomy of the seed. The process parameter depends on different geometrical parameter for instant to equalize different thickness of the paring to the filed emergence behaviour.

The 3d structure can be fast determined by 3d-CT. In contrary to technical products the shape of biological products is irregular. In this case it is difficult to determine relevant measuring quantities by automatic image processing.

1 Production steps of sugar beet seed

Sugar beet seed is a fruit with a wooden shell, pericarp and paring and the embryo in the cavity. The thickness of pericarp and paring varies strongly on the condition of breeding. Figure 1 shows the 3d reconstruction of a sugar beet seed (green ware) with about 10 µm voxel size. The 3d view shows the embryo within the cavity, the wooden paring and the sponge like pericarp. The diameter of the greenware varies between 1,5 and 4,5 mm.

During the production process the seed is polished removing pericarp and reducing thickness of paring. Fully filled seed is separated from half filled and empty seed using gravitation-counterflow sizer; polished seed is sieved to different calibre.

Fehler! Es ist nicht möglich, durch die Bearbeitung von Feldfunktionen Objekte zu erstellen.

Fig. 1: Reconstruction of a sugar seed beet

After polishing the seed is infold by pelleting material to a pill with 3,5 mm diameter. The chemical and physical composition of the pelleting material takes into account geometrical characteristic of different production batches.

3d-CT is being used at different stages of the production process. Each batch is characterised three times: First at the incoming goods inspection of green ware to get necessary information about the quality and for adjustment of production parameters, second after polishing, and third after sieving. The geometrical parameter of each batch is stored for quality control purpose.

2 Set up of the inspection system

The 3d-CT system consists of a sealed microfocal x-ray tube (max. 150 kV, 80 W, 5 µm to 50 µm focal spot size), a manipulation system, a flat panel x-ray detector and a cluster of 4 PC´s for data acquisition, reconstruction and 3d image processing [2]. Figure 2 shows the schematic diagram and figure 3 the photograph of the inspection system.

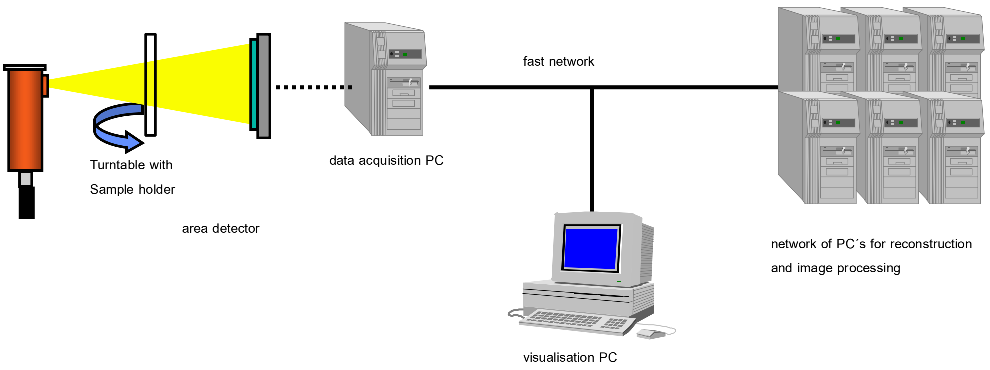

Fig. 2: Set up of inspection system

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Fig. 3: Inspection system

The voxel size varies between 10 µm and 200 µm to allow a wide range of application from examination of single seed with high resolution to inspection of single plants in manual mode. The cross sections are evaluated manually with the aid of visualisation software. In figure 4 a cross section of a seed with 10 µm voxel size is shown. The embryo fills completely the cavity; the diameter of the seed is about 4 mm and the thickness of paring amounts to 0,2 mm.

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Fig. 4: Reconstructed cross section of sugar beet seed, 10 µm voxel size

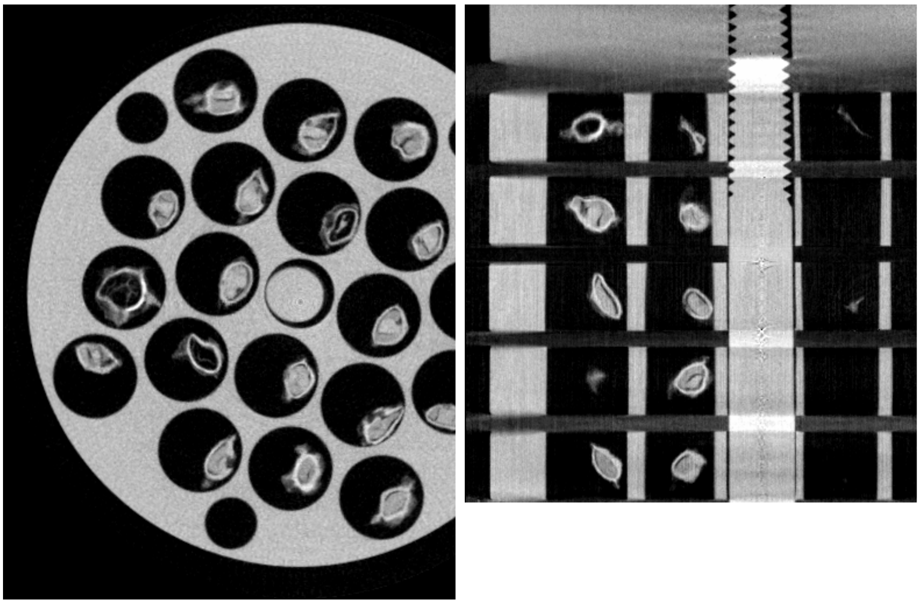
Statistical process control is performed in automatic mode with seed fixed in a carrier. In automatic mode the carrier with seed is measured and reconstructed within three minutes. A few seconds past acquiring the last projection automatic image process starts computing 100 seeds within two minutes. During the image processing the next carrier is fixed on the turn table of the CT system.

3 Automatic seed characterisation

To characterise sugar beet seeds we perform an automatic segmentation procedure to separate the different seed materials: Pericarp, paring, embryo, and cavity. This is done using an image processing sequence that consists of three main steps: Seed detection, seed segmentation, and seed feature extraction. A more detailed description of these steps is given in the following.

3.1 Seed detection

To perform seed segmentation we have to detect in a pre-processing step the seeds inside the volume data first. The seed mounting mainly consists of five plastic discs which are stacked on each other. Each disc has a certain number of drilled holes where the seeds are placed in. To achieve a perfect seed isolation the discs are separated via thin Styrofoam slices, see figure 5.



a) b)

Fig. 5: Reconstruction of the disc filled with sugar beet seeds. a) XY slice. b) XZ slice. carrier contains polished seed , 2 empty seed visible

Since the geometry of the discs and the resolution of the reconstructed volume are well known a template matching step using a model of the disc yields good seed localization. Creating a partial volume for each detected seed and queuing the volume into the runtime system for distributed image processing finishes the pre-processing step.

3. 2 Seed segmentation

After the seed detection in the pre-processing step we possess a list of seed volumes, i.e. each volume inside the list contains only one single sugar beet seed. Now the seed segmentation for separating the different materials can be performed for each seed volume independently of the other volumes.

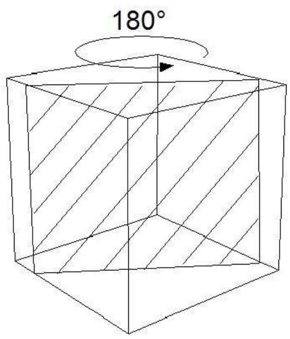
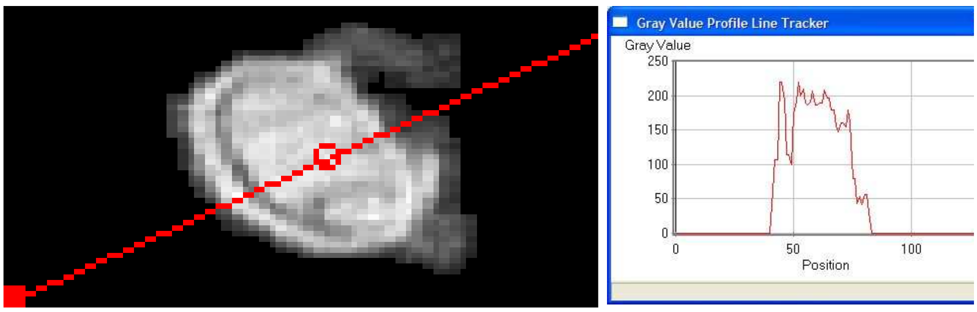


Fig. 6: Schematic illustration of creating central slices.

The segmentation of seed volume acts slice-by-slice where each slice is a central slice of the seed volume, see figure 6. Edge detection algorithms are used to find the borders of the different materials inside the central slice. The one-dimensional edge detection is performed on grey value profiles where the profiles represent radial lines, see figure 7.



a) b)

Fig. 7: a) Central slice of a seed volume with a radial line. b) Grey value profile of the radial line in a).

Merging the segmentation results of all radial lines into one image yields the segmentation of the whole central slice. Merging all central slices into one volume yields the segmentation of the whole seed volume. A comparison of the proposed method with segmentation by hand of an expert is shown in figure 8.

a) b) c)

Fig. 8: a) Original slice of a voxel volume. b) Segmentation of a) by hand. c) Automatic segmentation of a) using the proposed method.

3.3 Seed feature extraction

The final step of the automatic image processing sequence consists of calculating several features for the segmented regions and therefore for the materials of the examined sugar beet seed. At the moment the following features are determined for the total seed, each material, and certain material unions: Volume, minimal diameter, maximal diameter, and several form factors. Using these features a detailed characterization of a sugar beet seed can be performed.

3.4 Segmentation of pills in a batch

The smooth surface of pills and the knowledge of diameter support the segmentation of pills. The segmentation is performed in two steps – isolation of single pills, segmentation of pilling material from seed.

Single pills are isolated using a water shed transformation. Pilling material is separated from seed using a distance transformation and another water shed transformation.

Figure 9 visualises a CT-volume of a batch of pills and the segmentation into embryo, cavities, paring and pilling material

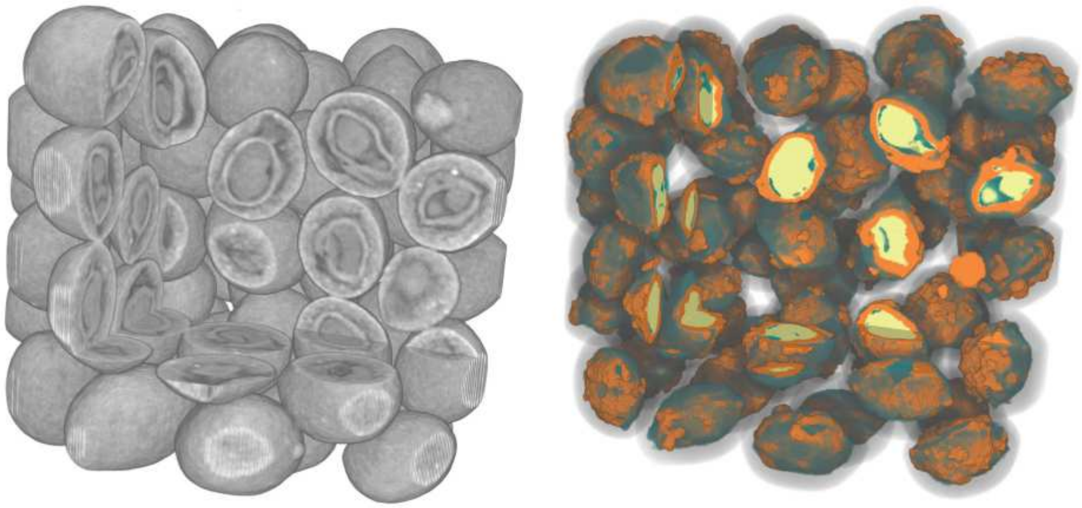


Fig. 9: Pills in a batch: Visualisation of pills (left) and segmentation (left), yellow: embryo, blue: cavities

4. Conclusion

The field emergence behaviour and the yield of sugar beet seed are largely determined by morphological and anatomical features of the fruit and seed, but also by the properties of the pelleting material. While traditional germination tests under optimal or altered conditions describe the behaviour of the seed, they do not offer any insight into the causes of the differences observed.

With the aid of 3D-CT the influence of different anatomical details to the growing of the seed and the fruit can be studied and important parameters can be searched out.

Using automatic 3d-CT in production control of sugar beet seed statistical information about the morphology of the batch is determined. The described 3d-CT system is being used successfully more than 4 years in seed industry to optimize and control the production process.

3d-CT allows further non-destructive analysis of morphological and anatomical influence factors and of the physical properties of pelleting material. Volume, shape and tissue structures can thereby be measured non-destructively inside the pill or fruit, and by sowing identical seed balls or pills these properties can be correlated with the field emergence, stress and yield behaviour of the seed.

References

[1] L. Blum, H. Masser, W. Rauh. Messen von Kunststoffteilen mit einer Multisensor-CT. In Koordinatenmesstechnik, VDI-Berichte 1914, 209-216, November 2005.
[2] M. Maisl, H. Reiter, M. Purschke, E. Zabler, M. Rosenberger-Koch. Application of industrial 3d computed tomography. Metall 55 (2001), 368-371.