Information system for analyzing, designing and managing drying and storage of cereal grains

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Abstract

An integrated information system was developed to support analysis, design and management of drying and storage of agricultural products, in particular – cereal grains. The system was composed of six modules dedicated respectively to: 1) 3D geometry data acquiring for investigated objects, based on a developed image analysis system, 2) simulating grain kernel drying, based on developed finite element inverse and direct models, 3) visualizing 3D models of investigated objects and presenting temperature and moisture content changes in time and space, 4) managing databases related to cereal grain drying, 5) computing drying air properties, simulating technological processes of drying and estimating performance of various drying systems and driers, and 6) selecting appropriate equipment and conditions for drying cereal grains, based on a developed decision support system. The problem domain was analyzed according to the UML 2.0 standards, the software was implemented in C++/CLI and C#, and the system was statically and dynamically tested on a basis of appropriately designed test cases.

Key words: grain drying and storage, inverse finite element modeling, image analysis, simulation and visualization of drying, decision support.

1 Introduction

In recent years, a great progress has been made in advancing technological know-how in the area of computer-aided analysis, design and management of grain drying and storing systems. The increasing role of computers in performing such operations makes it imperative that software quality attributes become fundamental. Although all quality attributes are of great significance, a special care should be taken to ensure that the software functionality, essential to a user, is wide ranging, it does what is needed, and users can well take advantage of it. For that reason development of a functional, reliable and efficient software satisfying elevated requirements of potential users is of particular importance.

Due to complexity of examined processes of cereal grain drying and storage, and in particular due to complex material and geometric structure of cereal grains, and also due to difficulties in adequate modeling interactions between a product and a surrounding fluid, construction of operational mathematical models is a difficult task. The problem is even more complicated because coefficients of mathematical models are often dubious, as direct determination of their values can lead to erroneous results, and in some cases it is not even possible. Therefore the authors examined an integrated approach based on:

- the image analysis to acquire data on 3D geometry of grain kernels (Weres and Olek, 2004, Koszela and Weres, 2005);
- the inverse finite element method to identify reliable coefficient values (Weres, 1998, Kujawa and Weres, 2005, Weres and Olek, 2005, Olek and Weres, 2006) and the direct finite element method to simulate cereal grain drying (Weres and Jayas, 1994, Weres, 1997);
- the 3D solid modeling to visualize investigated objects and changes in their properties during drying.
The objective of the paper was to develop an original and integrated information system increasing functionality, reliability and efficiency of computer-aided analysis, design and management of drying and storage of cereal grains.

2 Method of development and description of the system

The information system for analyzing, designing and managing drying and storage of cereal grains was developed according to software engineering standards. The problem domain was analyzed and represented by appropriate UML 2.0 diagrams. The software was implemented in C++/CLI and C# languages (Visual Studio 2005), and the system was statically and dynamically tested by originally designed test cases. The final system was constructed as a set of six integrated modules.

2.1 The image analysis module

The image analysis module was developed to collect data on 3D geometry of investigated objects and to generate corresponding 3D finite element meshes (Fig. 1).

![Image Analysis Module](image.png)

**Fig. 1** The image analysis module

2.2 The inverse and direct finite element analysis module

The finite element analysis module was developed to perform the inverse and direct modeling of grain kernel drying (Fig. 2). It was dedicated to simulate accurately and effectively the temperature and moisture content changes in individual kernels and thin layers of cereal grains. The module was equipped with several optimization algorithms to support identification of dubious coefficient values of mathematical models of drying. A detailed analysis of efficiency and accuracy of the coefficient
identification is possible, with respect to a selected procedure of local optimization (the variable metric with barrier functions and the trust regions) and global optimization (metaheuristics: simulated annealing, tabu search and genetic algorithm).

Fig. 2 The inverse and direct finite element analysis module

2.3 The visualization module

Fig. 3 The visualization module – representation of a 3D geometry model of a corn kernel and the temperature/moisture content as a function of time at a selected point of a kernel
The basic functions of the visualization module were to represent a 3D geometry model of an investigated object and to depict the temperature or the moisture content changes inside this object at selected time instants (Figs. 3, 4). Wire frame, surface and solid models were developed from the finite element mesh data generated by the image analysis module. Clipping selected planes and affine transformations like rotation, translation and scaling are supported.

2.4 The database module

The database module was developed to manage all necessary databases covering a broad spectrum of cereal grain drying issues (Fig. 5).
2.5 The drying simulation and performance analysis module

The drying simulation and performance analysis module was designed to determine quantities characteristic for drying air properties, to simulate the moisture content changes in technological processes of drying, and to estimate performance of various drying systems and driers (Fig. 6).

![Fig.6 The drying simulation and performance analysis module](image)

2.6 The decision support module

The decision support module was developed to advise farmers in their decisions concerning selection of appropriate equipment and conditions for drying cereal grains (Fig. 7).

![Fig.7 The decision support module](image)

4 Conclusion

Results of examination of the integrated information system developed and described in the paper pointed out that the analysis, design and management of complex systems of drying and storing cereal grains, often inefficient and partial so far, could be improved with respect both to computing efficiency and to accuracy of results, and above all with respect to a wide range of provided functionality.

5 References


Kurz, T. 2006. Komputerowe wspomaganie podejmowania decyzji w wyborze metod i urządzeń do suszenia i przechowywania ziarna zbóż (Computer decision support in selecting methods and equipment for drying and storing cereal grains). Master’s Thesis, Institute of Agricultural Engineering, Agricultural University of Poznan, Poland, 60 pp.


