Inter laboratory comparison on Computed Tomography for industrial applications in the slaughterhouses: CIA-CT comparison

An intercomparison on X-ray Computed Tomography (CT) for industrial applications in the slaughterhouses was organized by the Centre for Geometrical Metrology (CGM), Department of Mechanical Engineering, Technical University of Denmark (DTU) and carried out within the project “Centre for Industrial Application of CT scanning - CIA-CT”. In the comparison, 4 laboratories from 4 countries were involved, and CT scanned two synthetic phantoms, which were used instead of real pig carcasses. A phantom consists of several polymer components as Poly methyl methacrylate (PMMA), Polyethylene (PE) and Polyvinyl chloride (PVC). The polymer materials PMMA, PE and PVC represent tissue types as respectively: meat, fat, and bone. The one phantom represents a skinny pig carcass, when the other one represents a fat pig carcass with a higher content of fat (PE). The phantoms were produced through milling and cutting processes. The phantoms circulated among four participants and a total of six clinical CT scanners in Europe. The circulation took place between May 2011 and May 2012. Different volume measurands are considered, encompassing PMMA, PE, and PVC. The results of each participant are kept confidential. Each participant can identify their own results in this report using an anonymous identification number provided by the coordinator. Measuring instructions distributed by the coordinator were followed by all participants without problems. Participants carried out measurements and sent their results to the coordinator.

Reference values of both phantoms were measured by Danish Meat Research Institute (DMRI) before the circulation and determined by the coordinator using the principle of water displacement. A stability investigation on the phantoms was performed through 3 reproduced measurements over a 4 month period on a clinical CT scanner under the same conditions at DMRI. Investigations confirmed that the mean variation between the three time periods were quite small, below 30 mL. ANOVA tests demonstrated that the reproduced measurements were not significant (α=0.05), and the materials were stable enough. Depending on phantom and material, reference expanded uncertainties (k=2) ranging from approx. 0 mL up to approx. 10 mL were estimated. The most participants did not have any experience of how to outline uncertainty budgets. The expanded uncertainties stated by the participants are in the range 0-18 mL for both phantoms and all materials. Results by the single participants were compared with the reference values provided by the coordinator through the En value, where |En| < 1 indicates agreement between measurement results while |En| ≥ 1 shows disagreement. Out of a total of 6 single results obtained by the participants using CT scanning, 0% of the measurements yield |En| values less than 1, and 100% larger than 1. Systematic errors were detected for some participants on some of the measured volumes. It could be due to the specified tolerances defined by the participants for segmentation of the polymer materials. It was found that scale error correction particularly should be considered for some participants. The comparison shows that CT scanning on phantoms, generally speaking, is connected with uncertainties in the range 1-1090 mL, as compared to an uncertainty range of 0-10 mL using the principle of water displacement. Each participant can use the comparison results in the report to investigate the presence of systematic errors or an underestimation of uncertainties. Statistics related to the used equipment and procedures show that participants, in general, have followed state of the art procedures for their measurements. The phantoms are suitable artefacts for CT measurements of this kind.
Classification Methods for CT-Scanned Carcass Midsections: A Study of Noise Stability

Computed tomography (CT) has successfully been applied in medical environments for decades. In recent years CT has also made its entry to the industrial environments, including the slaughterhouses. In this paper we investigate classification methods for an online CT system, in order to assist in the segmentation of the outer fat layer in the mid-section of CT-scanned pig carcasses. Prior information about the carcass composition can potentially be applied for a fully automated solution, in order to optimize the slaughter line. The methods comprise Markov Random Field and contextual Bayesian classification, and are adapted to use neighbourhood information in 2D and 3D. Artifical Poisson noise is added to the provided dataset to determine how well each of the methods handles noise. Good noise handling will allow lower dose scannings. The investigated methods did not perform better than the reference model in terms of classification, but the MRF segmentation showed promising results in a case with extreme simulated noise.

The virtual knife

Since post World War II and until 2008 the Danish pig producing industry (DPPI) has been in a continuing state of growth. In spite of an ever fiercer competition DPPI has managed to protect its position as export leader by maintaining a focus on research and development. Today, DPPI is in a state of recession and must increase the efficiency if not to reduce the production capacity further. The industry recognizes that a more efficient use of the raw materials is one of the largest and most important challenges. To meet this challenge it is a necessity to get a better understanding of the biological variation of pigs. The development of models for describing the biological variation of pigs is one of the key components needed to attain a better sorting of the pig carcasses and an improved cutting in the abattoirs. Such models can be related to possible products, which can be related to potential yield and order books. The Danish Meat Research Institute (DMRI) is currently constructing a representative database of virtual representations of pigs using X-ray Computed Tomography (CT). The database will serve as the foundation for the diversity modeling of pigs and for extracting predictors of quality and optimal use. This thesis integrates well-known techniques from the medical image analysis into the development of tools for automated analysis of the morphology of pigs. E.g. elastic image matching has been applied to establish spatial correspondence between the virtual representations of pigs in the database. The establishment of spatial correspondence is an essential preprocessing step for most automated analysis using the database.
Image Registration and Optimization in the Virtual Slaughterhouse

This thesis presents the development and application of algorithms for the analysis of pig carcasses. Focus is on the simulation and quality estimation of meat products produced in a Danish slaughterhouse. Computed Tomography scans of pig carcasses provide the data used in the application. Image analysis is applied in order to imitate some of the cutting processes found in a slaughterhouse but also to give a quantitative measure of the composition of each carcass. The basis of the algorithms is non-linear image registration. This method finds the anatomical correspondence between a reference carcass and a template carcass. By iteratively comparing the transformed template with the reference a resulting dense deformation field is found. Propagating a set of landmarks from the reference coordinate system onto the template enables the simulation of slaughtering processes. Non-invasively estimating the quality of the slaughtering products provides a very valuable tool for use in the slaughterhouse in the future.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Image Analysis and Computer Graphics, Department of Photonics Engineering
Authors: Vester-Christensen, M. (Intern), Larsen, R. (Intern), Christensen, L. B. (Intern)
Publication date: Feb 2009

Modeling the Biological Diversity of Pig Carcasses

This thesis applies methods from medical image analysis for modeling the biological diversity of pig carcasses. The Danish meat industry is very focused on improving product quality and productivity by optimizing the use of the carcasses and increasing productivity in the abattoirs. In order to achieve these goals there is a need for more detailed information about pig carcasses in relation to measures of quality. Non-invasive imaging such as X-ray Computed Tomography (CT) can provide this very detailed information discerning the major tissue types. Medical image analysis provides the tools for extracting and modeling meaningful information from the vast amount of information available from non-invasive imaging data. The lean meat percentage (LMP) is a common standard for measuring the quality of pig carcasses. Measuring the LMP using CT and using this as a reference for calibration of online equipment is investigated, without the need for a calibration against a less accurate manual dissection. The rest of the contributions regard the construction and use of point distribution models (PDM). PDM’s are able to capture the shape variation of a population of shapes, in this case a 3D surface of a specific bone structure in the ham. These models can assist developers of robotic tools by enabling population based testing before actual construction of the tools. Sparse models are compared to the standard PCA based model and a method for fitting PDM’s to sparse data is proposed. The former provides more spatially localized modes of variation that are easier interpretable and the latter enables the use of PDM’s without the need for full point correspondence of new data. There is great potential in applying CT as non-invasive modality in the meat industry, e.g. in population based studies, for shape modeling and for analyzing carcass composition. In the future online CT applications can be used to make decisions on the use of each specific carcass by obtaining improved quality measures.

General information
State: Published
Contextual Analysis of CT Scanned Pig Carcasses

Knowledge of the weight of tissue types in pig carcasses is generally only available after manual dissection. The use of computed tomography (CT) has demonstrated to be a promising approach to gain knowledge on the lean meat weight (Romvari, 2005), but less effort has been put into gaining knowledge about the weight of other tissue types from CT. Knowing the weight of individual tissue types will directly give access to other measures such as the weight of the carcass and the Lean Meat Percentage (LMP). Until now, most analyses of CT scans have been based on the Hounsfield spectra that does not consider the spatial context in CT scan. Applying contextual methods from the field of image analysis we hope to make a virtual dissection of pig carcasses.
Coupled Shape Model Segmentation in Pig Carcasses

In this paper we are concerned with multi-object segmentation. For each object we will train a level set function based shape prior from a sample set of outlines. The outlines are aligned in a multi-resolution scheme wrt. an Euclidean similarity transformation in order to maximize the overlap of the interior between all pairs of outlines. Then the outlines are converted to level set functions. A shape model is constructed from the mean level set and the first few principal variations. We combine the prior model with an observation model based on the Chan-Vese functional assuming constant intensity levels inside the outline as well as in a narrow band outside the outline. The maximum a posteriori estimate of the outline is found by gradient descent optimization. In order to segment a group of mutually dependent objects we propose 2 procedures, 1) the objects are found sequentially by conditioning the initialization of the next search from already found objects; 2) all objects are found simultaneously and a repelling force is introduced in order to avoid overlap between outlines in the solution. The methods are applied to segmentation of cross sections of muscles in slices of CT scans of pig backs for quality assessment of bacon slices.

General information
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Organisations: Image Analysis and Computer Graphics, Department of Informatics and Mathematical Modeling, Department of Photonics Engineering
Authors: Hansen, M. F. (Intern), Larsen, R. (Intern), Ersbøll, B. K. (Intern), Christensen, L. B. (Intern)
Publication date: 2006

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Projects:

Engineering Strategies for improving the convenience food production- industry Case

National Food Institute
Period: 15/11/2012 → 21/04/2016
Number of participants: 7
Phd Student:
Pedersen, Søren Juhl (Intern)
Supervisor:
Kulahlci, Murat (Intern)
Vining, G. Geoffrey (Ekstern)
Main Supervisor:
Frosch, Stina (Intern)
Examiner:
Jørgensen, Bo Munk (Intern)
Christensen, Lars Bager (Intern)
Vanhatalo, Erik (Ekstern)

Financing sources
Monitoring Animal Wellbeing

Department of Applied Mathematics and Computer Science
Period: 15/12/2011 → 31/03/2016
Number of participants: 7
Phd Student:
Gronskyte, Ruta (Intern)
Supervisor:
Clemmensen, Line Katrine Harder (Intern)
Hviid, Marchen Sonja (Ekstern)
Main Supervisor:
Kulahci, Murat (Intern)
Examiner:
Ersbøll, Bjarne Kjaer (Intern)
Bergquist, Bjarne (Ekstern)
Christensen, Lars Bager (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering

Relations
Publications:
Monitoring Animal Well-being
Project: PhD

Spectral imaging of meat quality - color, texture and structure

Department of Applied Mathematics and Computer Science
Period: 01/12/2011 → 19/03/2015
Number of participants: 6
Phd Student:
Trinderup, Camilla Himmelstrup (Intern)
Supervisor:
Dahl, Anders Bjorholm (Intern)
Main Supervisor:
Conradsen, Knut (Intern)
Examiner:
Clemmensen, Line Katrine Harder (Intern)
Christensen, Lars Bager (Intern)
Parker, Alan (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Development and Application of Image Analysis and Multivariate Statistics in Industrial Aquaculture Feed Production

Department of Informatics and Mathematical Modeling
Period: 01/09/2009 → 22/11/2012
Number of participants: 6
Phd Student:
Ljungqvist, Martin Georg (Intern)
Supervisor:
Frosch, Stina (Intern)
Main Supervisor: 
Ersbøll, Bjarne Kjær (Intern)
Examiner: 
Conradsen, Knut (Intern)
Christensen, Lars Bager (Intern)
Misimi, Ekrem (Ekstern)

Financing sources 
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering
Project: PhD

Towards the Interactive ESS-Food Catalogue
Department of Informatics and Mathematical Modeling
Period: 01/05/2009 → 24/08/2012
Number of participants: 7
Phd Student: 
Laursen, Lasse Farnung (Intern)
Supervisor: 
Bærentzen, Jakob Andreas (Intern)
Christensen, Lars Bager (Intern)
Main Supervisor: 
Ersbøll, Bjarne Kjær (Intern)
Examiner: 
Carstensen, Jens Michael (Intern)
Madsen, Claus Brøndsgaard (Ekstern)
Sramek, Milos (Ekstern)

Financing sources 
Source: Internal funding (public)
Name of research programme: 1/3 DTU-stip, 2/3 FUR/andet
Project: PhD

New vision technology for multidimensional quality monitoring of food processes
Department of Informatics and Mathematical Modeling
Period: 01/05/2008 → 31/08/2011
Number of participants: 6
Phd Student: 
Dissing, Bjørn Skovlund (Intern)
Supervisor: 
Adler-Nissen, Jens (Intern)
Main Supervisor: 
Ersbøll, Bjarne Kjær (Intern)
Examiner: 
Jørgensen, Bo Munk (Intern)
Christensen, Lars Bager (Intern)
Parkkinen, Jussi (Ekstern)

Financing sources 
Source: Internal funding (public)
Name of research programme: 1/3 DTU-stip, 2/3 FUR/andet
Project: PhD

Online CT-scanning af slagtesvin
Department of Informatics and Mathematical Modeling
Period: 01/05/2008 → 28/09/2011
Number of participants: 7
Phd Student: 
Mosbech, Thomas Hammershaimb (Intern)
Supervisor:
Christensen, Lars Bager (Intern)
Larsen, Rasmus (Intern)
Main Supervisor:
Ersbøll, Bjarne Kjær (Intern)
Examiner:
Conradsen, Knut (Intern)
Brandt, Sami (Ekstern)
Bünger, Lutz (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 DTU-stip, 2/3 FUR/andet
Project: PhD

The Virtual Slaughterhouse - Constructing a virtual Knife
Department of Informatics and Mathematical Modeling
Period: 01/01/2006 → 01/07/2009
Number of participants: 6
Phd Student:
Hansen, Mads Fogtmann (Intern)
Supervisor:
Christensen, Lars Bager (Intern)
Main Supervisor:
Larsen, Rasmus (Intern)
Examiner:
Nielsen, Allan Aasbjerg (Intern)
Bajcsy, Ruzena (Ekstern)
Modersitzki, Jan (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 DTU-stip, 2/3 FUR/andet
Project: PhD

CT Scanning and Automated Segmentation of Pig Bodies
Department of Informatics and Mathematical Modeling
Period: 01/07/2005 → 11/02/2009
Number of participants: 6
Phd Student:
Vester-Christensen, Martin (Intern)
Supervisor:
Christensen, Lars Bager (Intern)
Main Supervisor:
Larsen, Rasmus (Intern)
Examiner:
Nielsen, Allan Aasbjerg (Intern)
Allen, Paul (Ekstern)
Barillot, Christian (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU, Samfinansiering
Project: PhD

Modellering af biologisk diversitet hos grise
Department of Informatics and Mathematical Modeling
Period: 01/02/2005 → 02/02/2009
Number of participants: 6
Phd Student:
Erbou, Søren Gylling Hemmingsen (Intern)
Supervisor:
Christensen, Lars Bager (Intern)
Main Supervisor:
Ersbøll, Bjarne Kjær (Intern)
Examiner:
Aanæs, Henrik (Intern)
Darvann, Tron Andre (Intern)
Vangen, Odd (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU, Samfinansiering
Project: PhD

Anvendelse af specielle fibre i optiske sensorer
Administration
Period: 01/06/1987 → 26/09/1994
Number of participants: 3
Phd Student:
Christensen, Lars Bager (Intern)
Main Supervisor:
Stubkjær, Kristian (Intern)
Examiner:
Tromborg, Bjarne (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Gammel ordning u/skema-SU
Project: PhD