Automatic Image Segmentation for Microwave Tomography (MWT): From Implementation to Comparative Evaluation

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Abstract

Inspired by its high performance in image-based medical analysis, this poster paper explores the use of advanced segmentation techniques for industrial Microwave Tomography (MWT). Our context is the visual analysis of moisture levels in porous foams undergoing microwave drying. We propose an automatic segmentation technique—MWT Segmentation based on K-means (MWTS-KM) and demonstrate its efficiency and accuracy for industrial use. MWTS-KM consists of three stages: image augmentation, grey-scale conversion, and K-means implementation. To estimate the performance of this technique, we empirically benchmark its efficiency and accuracy against two well-established alternatives: Otsu and K-means. To elicit performance data, three metrics (Jaccard index, Dice coefficient and false positive) are used. Based on our experiments, our results indicate that MWTS-KM outperforms the well-established Otsu and K-means.

CCS Concepts

• **Human-centered computing → Visualization design and evaluation methods**; • **Computing methodologies → Image segmentation**.

Keywords

Image Segmentation, Otsu, K-means, Microwave Tomography

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1 Introduction

Image segmentation is one of the most commonly used methods to classify the pixels of an image correctly in decision oriented applications. Due to its capacity for distinguishing various features [2], it is able to divide an image into a number of discrete regions so that the pixels have high similarity and high contrast amongst regions [1]. It has been successful on Microwave Tomography (MWT) system [4]. MWT is a non-ionizing imaging technique that provides a quantitative image of the dielectric profile object of interest (OI) [5]. In this poster paper, we focus on using MWT to measure a specialized industrial process—microwave drying for porous foams. The difference between dry and non—dry parts of the foam is represented by allocating different colors to each region as depicted in Figure 1, where the blue especially the dark-blue parts stand for lower moisture level than the yellow parts, meaning that these parts are drier. For such an (input) image, segmentation is a way to create an (output) image which is more meaningful and easier to analyze for the human eye. Using segmentation, the objective is to visualize the low moisture areas in MWT images.

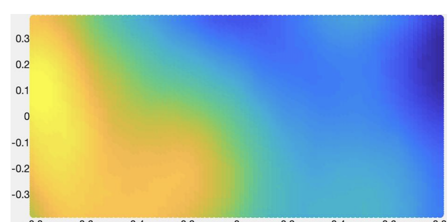

Figure 1: Example of MWT image from our 14 samples (image no. 11). Blue means lower moisture, yellow means higher moisture.

2 Methods

Our proposed algorithm—MWT Segmentation based on K-means (MWTS-KM)—is established based on the basic K-means algorithm [3]. It combines image augmentation, followed by grey-scale image conversion, and conventional K-means into our proposed automatic algorithm. The pipeline diagram shown in Figure 4 illustrates its structure and components. For benchmark comparison, we use Otsu [6] and K-means [3] algorithms. To evaluate the accuracy obtained from our segmentation algorithms, the similarity and false positive rate are measured by jointly applying three criteria: Jaccard index, Dice coefficient and false positive.

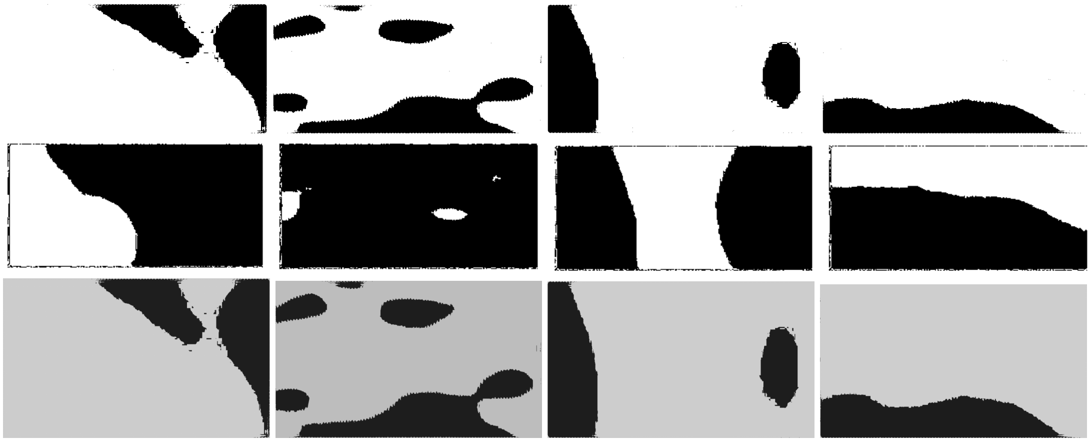

Figure 2: Comparison of three segmentation results: The first row shows results when using Otsu, second row when using K-means and third row are output images from MWTS-KM (based on input images nos. 11, 12, 13, 14). Segmentation outcome shows low moisture (dry) as black areas.

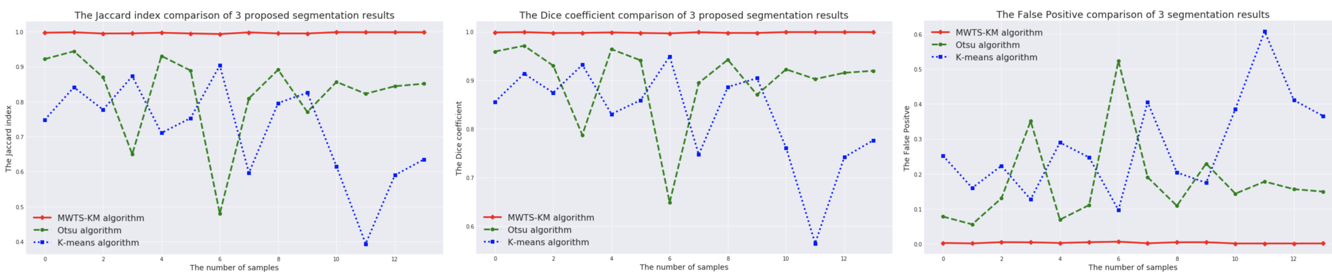

Figure 3: Accuracy measures (left to right: Jaccard index (0=low to 1=high), Dice coefficient (0=low to 1=high), and false-positive ratio (0=high to 1=low).

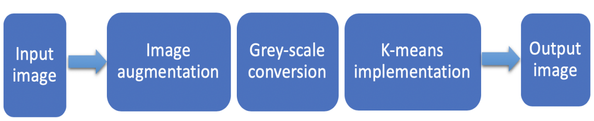

Figure 4: The proposed MWT Segmentation pipeline based on K-means (MWTS-KM) algorithm.

3 Results

In our analysis, we intend to categorize our MWT image into two parts; low moisture area and other area. We chose 4 (images nos. 11, 12, 13, 14) of 14 samples to be shown in this paper, as shown in Figures 2 and Figure 3, the exhaustive segmentation results with the respect of MWTS-KM, Otsu and K-means. The dark areas denote the low moisture areas that are the desirable consequences we want.

4 Conclusions

MWTS-KM in particular outperforms both Otsu and K-means in our study, which achieves nearly one of both Jaccard index and Dice coefficient in the whole 14 segmentation results. Furthermore, the false positive values for MWTS-KM attain almost zero in each trial, which would be pertained to excellent performance.

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References

[1] Nameirakpam Dhanachandra, Khumanthem Manglem, and Yambem Jina Chanu. 2015. Image Segmentation Using K -means Clustering Algorithm and Subtractive Clustering Algorithm. *Procedia Computer Science* 54 (2015), 764 – 771. https://doi.org/10.1016/j.procs.2015.06.090

[2] O. M. Dorgham. 2017. Automatic body segmentation from computed tomography image. In *2017 International Conference on Advanced Technologies for Signal and Image Processing (ATSIP)*. 1–5. https://doi.org/10.1109/ATSIP.2017.8075612

[3] John A Hartigan and Manchek A Wong. 1979. Algorithm AS 136: A k-means clustering algorithm. *Journal of the Royal Statistical Society. Series C (Applied Statistics)* 28, 1 (1979), 100–108.

[4] Alan Jose, S.Ravi, and M.Sambath. 2014. Brain Tumor Segmentation Using K-Means Clustering And Fuzzy C-Means Algorithms And Its Area Calculation. *International Journal of Innovative Research in Computer and Communication Engineering* 2, 3 (Mar 2014), 1–9.

[5] P. Mojabi, M. Ostadrahimi, L. Shafai, and J. LoVetri. 2012. Microwave tomography techniques and algorithms: A review. In *2012 15 International Symposium on Antenna Technology and Applied Electromagnetics*. 1–4.

[6] Nobuyuki Otsu. 1979. A threshold selection method from gray-level histograms. *IEEE transactions on systems, man, and cybernetics* 9, 1 (1979), 62–66.