

Title: Defect Sizing via *Grayscale Thresholding* Technique Applied to Digital Radiographic Images of Industrial Materials — with Special Focus on Nuclear Fuels

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ABSTRACT

Determination of the size of a defect in a given material is important from industrial usage point of view. In this work, a computational technique has been developed that takes a humble step forward from just qualitative description of *defect*, such as “big” or “small” to its area-wise quantification. Our program (by the name “*DEFAREA*”) accepts a 2D grayscale image of an investigated specimen as input and sizes the irregular shaped defects contained therein in terms of the area occupied by them. In case where a defect feature is of regular shape being a projected image of a cylinder or a sphere the program is also able to produce volumetric results. The program exploits the fact that defects offer color contrasts that are different from the rest of the image (such as bone fracture in X-ray radiograph). It is based on *grayscale thresholding* (GT) whereby it first iterates down to compute a minimum value of graylevel that separates the first peak from the rest of the distribution in the grayscale spectrum of the given input image. This threshold, which is representative of a particular shade of gray color, is then used to identify, select and count the number of pixels which have graylevel values below the computed threshold. The number of segmented pixels within the whole image size then easily produces not only a numeric fraction of the defective portion of inspected specimen but also the area occupied by the defect if the physical sizes and dimensional measurements of the specimen are known. The main part of the algorithm, however, revolves around devising a reliable computational method to obtain a certainty range in the reported defect size.

Certainty range is needed as there physically exists a transition region (TR) between the defective and the immaculate parts of the investigated object that can not be put in either category. TR offers lesser contrast with the flawless part of the image than the pure defect areas. So a given defect is doubly quantified with and without appending the transition region around it with the aid of user-defined adjustability in the computed grayscale threshold. Then finally an average value of defect size is calculated along with an associated certainty.

The presented algorithm is validated against physical measurements of some locally fabricated metallic plates having drilled holes of known sizes simulated as defects in them in which the results indicate that it correctly selects and quantifies at least 94.7% of the actual required regions of interest in a given image and it gives less than 8% false alarm rate.

The algorithm is then applied to sizing of a wide range of defects commonly encountered in nuclear industry regarding reactor fuels. The images of nuclear fuels used as input in the program are collected from a reference standard source of neutron radiographs. The present work confirms the ability to quantify various kinds of defects such as chipping in nuclear fuel, cracks, voids, melting, deformation, inclusion of foreign materials, heavy isotope accumulation and non-uniformity etc. The classes of fuel range from those of research and power reactors to fast breeders, from fresh nuclear fuel to post-irradiate, and from pellets to annular and vibro-compacted fuel. It is also demonstrated that the program can handle a variety of image sizes, displays several output modes of image segmentation and works well without the need of any smoothing or eroding morphological operations.