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EVALUATING THE IMAGE QUALITY OF MAMMOGRAPHY PHANTOM IMAGES

EVALUACIÓN DE LA CALIDAD DE IMAGEN EN IMÁGENES DE FANTOMA MAMOGRÁFICO

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Abstract: Image quality assessment in medical imaging constitutes a relevant contribution to improving the reliability and productivity of healthcare processes. In this work, an approach based on the acquisition of mammography phantom images is presented to evaluate their quality and analyze the relationship with image quality assessment tasks performed by human observers. A dataset was constructed from X-ray images acquired on a mammography system using an accreditation mammography phantom under different exposure conditions. On these images, objective image quality features such as signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were analyzed. Additionally, a tool for subjective image evaluation was developed, in which expert observers rated the visibility of the phantom structures. The proposed approach aims to support the development of objective image quality measures that are consistent with the performance of visual structure detection in quality control images for mammography equipment.

Keywords: image quality assessment; accreditation phantom; mammography; SNR/CNR.

Resumen: La evaluación de la calidad de la imagen en el ámbito de la imagen médica constituye una contribución relevante para mejorar la fiabilidad y la productividad de los procesos sanitarios. En este trabajo se presenta un enfoque basado en la adquisición de imágenes fantasma de mamografías para evaluar su calidad y analizar la relación con las tareas de evaluación de la calidad de la imagen realizadas por observadores humanos. Se construyó un conjunto de datos a partir de imágenes de rayos X adquiridas en un sistema de mamografía utilizando un fantoma de mamografía acreditado en diferentes condiciones de exposición. En estas imágenes se analizaron características objetivas de calidad de imagen, como la relación señal-ruido (SNR) y la relación contraste-ruido (CNR). Además, se desarrolló una herramienta para la evaluación subjetiva de imágenes, en la que observadores expertos calificaron la visibilidad de las estructuras del fantoma. El enfoque propuesto tiene como objetivo apoyar el desarrollo de medidas objetivas de calidad de imagen que sean coherentes con el rendimiento de la detección visual de estructuras en imágenes de control de calidad para equipos de mamografía.

Palabras clave: Evaluación de la calidad de imagen; fantoma de acreditación; mamografía; SNR/CNR.

1. INTRODUCTION

Breast cancer represents a major public health problem in Colombia, with approximately 2,226 women dying each year from this disease [1]. According to [2] in Colombia, early detection of breast cancer is based on three key activities: undergoing a mammogram (MG) every two years in women between 50 and 69 years of age, or earlier at the physician's discretion; conducting an annual clinical breast examination in women aged 40 years and older as part of routine physical assessments; and promoting monthly breast self-examination as a self-care practice.

In Colombia, the Ministry of Health has adopted several initiatives aimed at reducing the incidence, mortality, and disability associated with breast cancer, including the promotion of timely, accurate, and coordinated interventions within the healthcare system [3, 4]. Among the strategies currently promoted by the government is monitoring the quality of mammography services across the country.

To perform quality control procedures on mammography equipment, a phantom is used, consisting of a block of polymethyl methacrylate (PMMA) that simulates the X-ray attenuation of an average compressed breast and contains embedded structures. System performance is evaluated by radiology teams through human visual identification of visible objects for each structure type, including fibers, microcalcifications, and masses. Figura 1 shows a reference image of the ACR RMI 156.

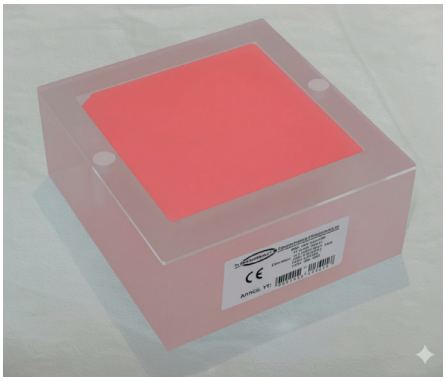

Figura 1. Phantom ACR RMI 156 [5]

In this work, through the integration of the dataset and expert opinions, we aim to establish a basis for the development of automated solutions that support quality control procedures for mammography equipment and contribute to the early detection of breast cancer.

2. MATERIALS AND METHODS

The research was conducted under a quantitative, descriptive, and correlational approach. In the first stage, a dataset of mammography phantom (MG) images was prospectively constructed at Clínica Imbanaco, a high-complexity healthcare institution located in Cali, Colombia. Subsequently, the structures present in the images were analyzed and a subjective study was conducted, in which a group of evaluators consisting of medical imaging technologists, medical physicists, radiologists, and biomedical and electronic engineers with experience in medical imaging, from different institutions in the city of Cali, performed structure scoring and perceptual quality assessment on an assigned dataset.

To conduct the subjective study, the project was approved by the Health Research Ethics Committee of the Faculty of Health Sciences at Pontificia Universidad Javeriana Cali.

3. ANALYSIS AND RESULTS

A custom graphical user interface (GUI) was developed in MATLAB®, consisting of four modules. The first module allowed the registration of the evaluator's identifier for the study; the second and third modules displayed images for each evaluator to identify the number of disks, fibers, and microcalcification groups; and the fourth module enabled participants to rate the perceptual quality of each mammography phantom image (PMGI).

Previous work by the research group analyzed objective image quality metrics in mammography phantom images (PMGI), such as signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), and natural scene statistics (NSS), under different acquisition conditions, establishing an initial quantitative characterization of image quality [6]. The subjective study included a dataset composed of ten undistorted PMGIs with high CNR values, thirty distorted PMGIs, five undistorted projected PMGIs, and thirty-five distorted and projected PMGIs. Here, the projections refer to spatial transformations of the PMGIs applied to alter the apparent location of structures. Projections were performed in vertical (V), horizontal (H), and diagonal (D) directions in order to minimize bias derived from the spatial memory of object locations. The complete dataset consisted of eighty PMGIs. Figura 2 shows the flow diagram of the tool.

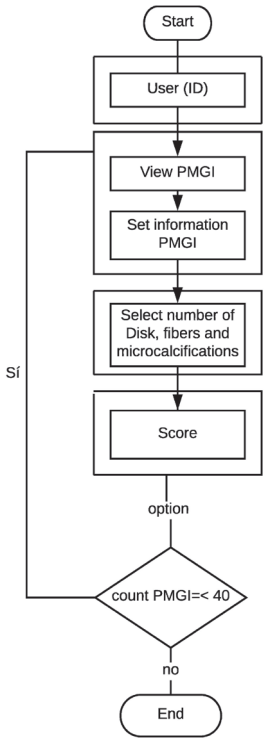

Figura 2. Tool diagram

The evaluations were conducted by twenty-one experts in two 30-minute sessions under controlled lighting conditions, using a Spyder5 PRO device to calibrate the display according to industry color standards. All expert evaluations were recorded through the GUI for subsequent data processing and analysis.

4. CONCLUSIONS

Since the CNR of PMGIs is related to the detection of structures in the image, and the attenuation coefficient of microcalcifications is higher than that of fiber and disk-type structures, this factor was fundamental in the construction of the dataset for the subjective study.

The evaluation of PMGIs is associated with the selection of disk, fiber, and microcalcification group structures. According to the time required to perform the task, it was identified that evaluators may need between 20 and 40 minutes to assess 40 images. Due to the repetitive selection of structures in PMGIs, visual fatigue may also occur among evaluators.

The MATLAB® based graphical user interface (GUI) enabled the integration of structure detection information from PMGIs and the assignment of a quality score to each image. These results were consolidated to support subsequent data processing stages, such as the analysis and modeling of image quality with the aim of facilitating the prediction of diagnostic image quality.

5. ACKNOWLEDGMENTS

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