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Dose Rate Estimation by Extracting and Analyzing Colors from an Image Generated by a CMOS Image Sensor

W. Viana[1], A. Z. Mesquita[1], T. C. Alonso[1], D. S. Calheiro[1], A. C. O. Alves[2]

[1] *wallacy.viana@gmail.com CDTN/Cnen. Campus da UFMG – Pampulha, Belo Horizonte -MG*
[1] *amir@cdtn.br CDTN/Cnen. Campus da UFMG – Pampulha, Belo Horizonte -MG*
[1] *alonso@cdtn.br CDTN/Cnen. Campus da UFMG – Pampulha, Belo Horizonte -MG*
[1] *daniel.calheiro@cdtn.br CDTN/Cnen. Campus da UFMG – Pampulha, Belo Horizonte -MG*
[2] *annaclara98alves@gmail.com Cefet-MG. Av. dos Imigrantes, 1000 - Bairro Vargem - Varginha – MG*

1. Introduction

In recent years, the use of image sensors utilizing complementary metal oxide semiconductors (CMOS) have become a new trend in radiation detection due to factors such as their low cost, general availability, and their direct response to X-rays and gamma rays. [1]
This paper presents the estimation of dose rate using a process of extracting the predominant colors of an image taken from a CMOS image sensor while being irradiated, and analyzing their percentage in relation to the image as a whole.
In a project in which the development of a remotely controlled submersible robot (ROV) was carried out, a generic camera commonly used in surveillance devices or car maneuvering assistance systems was used as means of visual inspection. Said camera had a CMOS sensor, and it was subjected to tests under different dose rates of gamma radiation at the CDTN gamma irradiation laboratory.
The Gamma Irradiation Laboratory – LIG, located on the CDTN premises is classified as a Category II Multipurpose Panoramic Irradiator, manufactured by MDS Nordion in Canada, Model/serial number IR-214 and type GB-127, equipped with a cobalt-60 source dry stoke with maximum activity of 2,200 TBq or 60,000 Ci. [2]
It is worth mentioning that there are also applications that can be installed on smartphones in order to carry out measurements of low dose rates using the image sensors installed on them. However, the process used by these apps consists of the contrast between a static background and a count of the number of CMOS pixels that light up during irradiation. [3]

2. Methodology

Several tests were carried out under different dose rates, with the aim of carrying out resistance tests on the ROV's internal circuit which was equipped with the before mentioned camera. It is worth highlighting here the possible variation of 10% in the recorded dose.
Samples were taken from the images, specifically from a black square of 100 by 100 pixels on their corners. Figure 1 shows the samples taken from the images, at three different dose rates.

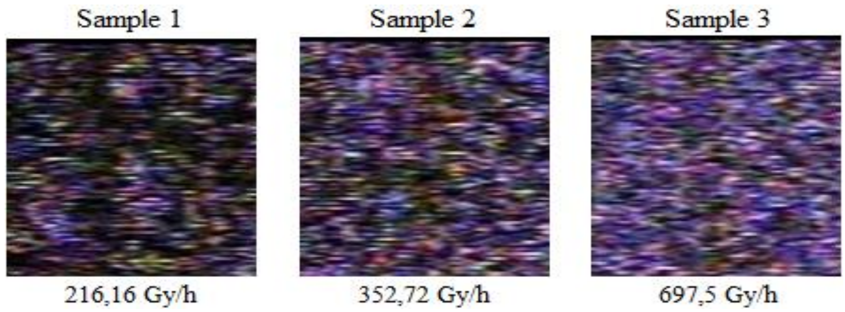

Figure 1: Three samples taken from three different images at different dose rates.

In all tests, the camera exhibited artifacts due to the passage of electrons in the circuit during irradiation, returning to the normal state as soon as irradiation stopped. A critical camera failure occurred at a total dose of approximately 250 Gy, 45 minutes after the tests began. This critical failure was repeated in all subsequent tests a few seconds after the start of exposure, indicating permanent damage to the camera's semiconductors, which prevented further data collection.

It is also worth highlighting the capture of an image in which the dose rate was unknown. Such an image was captured during the cover-up of the cobalt-60 source, which resulted in such an unknown dose rate. This image generated sample number four (Fig. 2).

Figure 2: Sample number 4, taken from an image of unknown dose rate.

Subsequently, an online tool was used to extract the predominant colors in the image. The PHP Image Color Extract tool extracts the most common colors from an image file. Color values are displayed in hexadecimal, along with their percentage in relation to the image. It is worth noting that such color extraction can be performed with most graphic design programs. [4]

The collected data were then displayed in Table I, and the control group was added in order to establish a standard.

Table I: Percentage of each predominant color extracted from the samples.

Color (Code)	Control (%)	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Sample 4 (%)
Black (#000000)	100	51.6	24.51	8.03	84.9
Gray (#646464)	0	25.25	38.78	47.36	9
Blue (#000064)	0	6.4	10.36	10.07	1.79
Purple (#640064)	0	6.18	11.8	15.45	1.23
Red (#640000)	0	4.14	3.4	1.17	1.54
Light gray (#c8c8c8)	0	1.71	3	3.24	0.2
Yellow (#646400)	0	1.51	1.03	0	0.7
Light blue (#6464c8)	0	1.2	3.48	9.09	0.09

Using the MiniTab® program, it was possible to create graphs and generate trend lines which in turn generated equations for each of the colors, making it possible to carry out calculations to estimate the dose rate using the percentage values of each color in sample four (Fig. 2).

3. Results and Discussion

Considering the physical integrity of the camera, the radiation darkened the glass lens in front of the camera, making it significantly difficult to view the image at the end of the tests. It is possible to compare the data regarding the radiation resistance of the camera collected through the tests with other data collected by other authors. Tests were performed using a similar camera, which showed SNR-related damage at different irradiation rates, but even at 100 Gy/h for 1 h, totaling a dose of 100 Gy, the damage was still small. [5]

This was confirmed by the tests carried out, as even with a dose of around 200 Gy, the camera still worked normally.

Carrying out the calculations using the equations generated from the trend lines mentioned above, and considering the percentages of colors in sample four, it is possible to construct a graph which demonstrates the predicted dose rate for each of the colors (Table I).

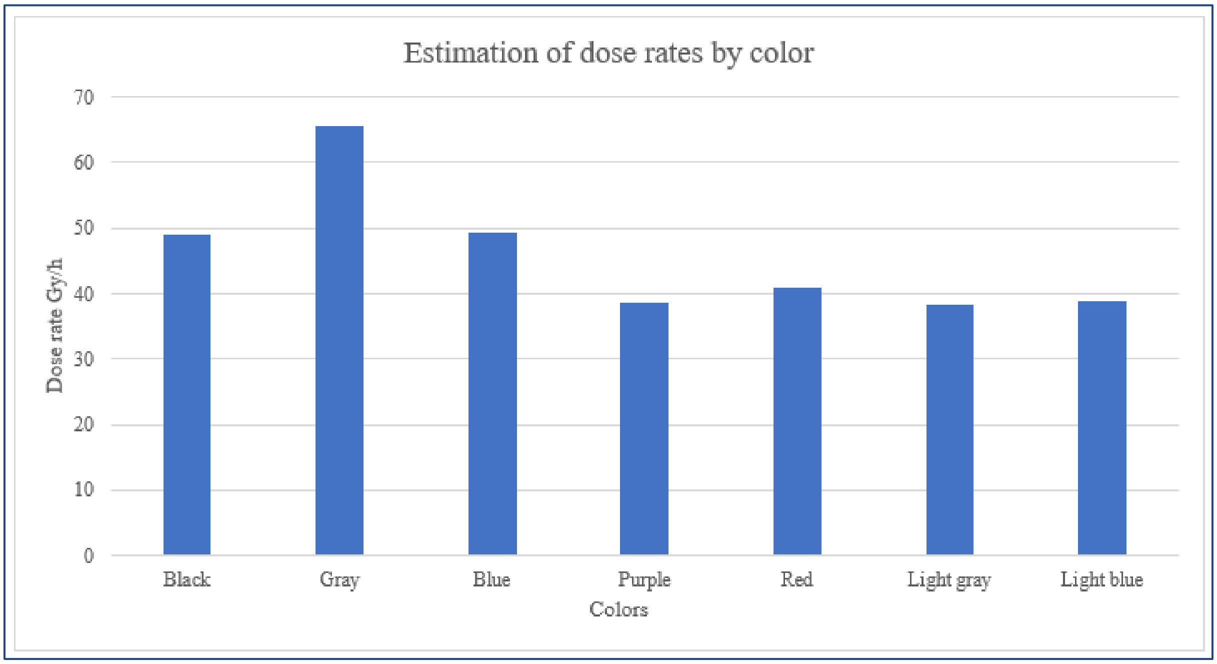

Figure 3: Graph demonstrating the predicted dose rate by each color.

Analyzing the results, it is possible that there were small discrepancies in relation to some colors, however, they all appeared between the range of 38 Gy/h and 65 Gy/h. Taking the arithmetic mean of the previously mentioned values, a value of approximately 45.84 Gy/h is obtained, adjusted for the possible variation of 10% previously mentioned.

4. Conclusions

Nuclear technology has been promoted and applied throughout the world, but as it poses a certain threat to public safety, methods of detecting nuclear radiation are necessary. Image sensors using complementary metal oxide semiconductors (CMOS) present a promising addition to radiation detection methods.

This paper analyzed a method for estimating high dose rates using a camera. To this end, image color extraction and quantization methods were used, as well as mathematical models in order to recognize patterns in color variations and estimate the dose rate in an image whose dose rate was previously unknown.

The results of the dose rate estimate were also consistent with the appearance of the image presented in sample four, as it follows mathematical models that were generated from other images, and the fact that the radiation source was being covered at the time.

The camera's irradiation tests also obtained results consistent with previously carried out tests in terms of radiation resistance.

Subsequently, more tests should be carried out with better cameras, in tests with varying dose rates and of shorter duration, in order to preserve the integrity of the camera for more comprehensive data collection and creation of more accurate mathematical models. An algorithm can also be developed in order to process and analyze this data automatically.

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