IONIZING RADIATION DETECTION ALGORITHM FOR CMOS SENSOR FROM CONSUMER CAMERA DEVICE

Megat Harun Al Rashid Megat Ahmad[1,3*], Nashihah Ab Karim[1], Lahasen@Normanshah Dahing[2], Hearie Hassan[2], Roslan Yahya[2], Suhairy Sani[1], Ismail Mustapha[1], Nor Pa'iza Mohamad Hasan[2] and Shaharuddin Sayuti[1]

[1]*NDT-Material Structural Integrity (NDT-MSI), Industrial Technology Division, Agensi Nuklear Malaysia, 43000 Kajang, Selangor, Malaysia*
[2]*Plant Assessment Technology (PAT), Industrial Technology Division, Agensi Nuklear Malaysia, 43000 Kajang, Selangor, Malaysia*
[3]*Puspati ION Technology Solution (PITS), Lorong Villa Gemilang, Kampung Sungai Buah Dalam, 43800 Dengkil, Selangor, Malaysia*

∗Corresponding author: megatharun@nm.gov.my

ABSTRACT

Laplacian of Gaussian (LoG) algorithm was evaluated to quantify ionizing gamma events on CMOS sensor in a consumer webcam. The ionizing events measurements were carried out by fully covering the CMOS sensor with aluminum foil thus allowing only gamma photons to reach the CMOS sensor. The CMOS operation was done by recording movie of ionizing events with ^{241}Am as gamma radiation source. LoG algorithm was then applied on the movie file frame by frame. The LoG algorithm was found capable to discriminate cluster of bright pixels with values that were assumed to correspond to charge collection for each individual ionizing event. The very thin layer of the CMOS however made it difficult to build gamma spectrum because of low ionizing energy deposition.

ABSTRAK

Algoritma pengoperasian Laplace ke atas Gauss (LoG) telah dinilai sebagai algoritma pengiraan untuk mengira bilangan kejadian pengionan gamma pada pengesan CMOS di dalam kamera web barangan konsumer. Pengukuran kejadian pengionan dilaksanakan dengan menutup sepenuhnya pengesan CMOS dengan kerajang aluminium supaya hanya foton gamma sahaja yang boleh sampai ke pengesan CMOS. Operasi CMOS dilakukan dengan merakam filem kejadian pengionan dengan ^{241}Am sebagai sumber radiasi gamma. Algoritma LoG kemudiannya digunakan ke atas fail filem tersebut bingkai ke bingkai. Algoritma LoG didapati berupaya mengenalpasti kelompok dengan piksel cerah yang nilainya sepadan dengan pengumpulan cas bagi setiap kejadian pengionan. Namun begitu, lapisan CMOS yang sangat nipis menyukarkan pembangunan spektrum gamma yang berdasarkan jumlah nilai pengumpulan cas ini.

Keywords: Laplacian of gaussian, CMOS, ionizing radiation, sensor.

INTRODUCTION

Inexpensive and readily available consumer camera device with CMOS active pixel sensor (APS) architecture[1,2] has been shown able to detect ionizing radiation either from cosmic sources[3- 6] or from terrestrial sources[7-9]. An ionizing event on this detector can be observed as clustering of bright pixels on the detector image frame. X-ray spectrum was reportedly built from these clustering of bright pixels by simple discrimination of pixel brightness[10]. The ability to detect higher energy photons like gamma photons however may require more sophisticated approach perhaps by singularizing and characterizing each cluster before quantification and identification of radiation sources.

These bright cluster of pixels are quite similar in appearance to bright celestial objects in astronomical image[11] observation. Similar method for detecting these astronomical objects therefore can be applied as a programmable tool to detect ionizing events on CMOS image frame. The Laplacian of Gaussian (LoG) algorithm is one of the technique quite commonly used for astronomical objects identification by edge detection[12]. This technique is known as blob detection. Herein for this work, we applied the LoG to identify the central pixel position for each ionizing event on the CMOS image frame.

The information on ionizing event position not only allows us to quantify ionizing event but also provide a reference area coordinate for further data processing, in particular with regards to computation of charge collection values that may be useful to discriminate energy spectrum. Apart from this, the ability to have an accurate counting algorithm will enable the CMOS sensor to be evaluated as dosemeter.

In the LoG algortihm, an image file containing pixel values according to function $f(x,y)$ is convolved using a Gaussian filter[13]:

$$g(x,y,\sigma) = \frac{1}{2\pi\sigma} e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad \text{Eq. 1}$$

resulting in a scale space representation $L(x,y;\sigma) = g(x, y, \sigma) * f(x,y)$. Laplacian operation is then computed for this representation:

$$\nabla^2 L = L_{xx} + L_{yy} \qquad \text{Eq. 2}$$

In this work, we applied the LoG to find the coordinates for each bright cluster of pixels in the CMOS image frame. Each of this cluster was considered to represent a single ionizing event. Subsequent computation for charge collection and discrimination was then performed to evaluate the CMOS sensor as gamma spectrometer.

MATERIAL AND METHODS

The description of CMOS sensor used and experimental procedure were the same in previous report[14]. The method of measurement however was modified. In our previous work, data collection and processing were done simultaneously during experiment. In this work, the CMOS sensor instead functioned as a camera in which a movie of ionizing events was first taken for each radiation exposure before data processing. This resulted in more data frame per exposure time. The radiation measurement has a movie recording cycle of about 3.3 seconds (99 frames or 30 frames/second). A total of three measurements were carried out for each source to detector distance of 0 to 5 cm. Noise removal from all image data frames were performed by subtracting pixel value with the median value obtained for each frame. The source of radiation used was ^{241}Am (100 mCi) covering only tens keV of gamma energy. Table 1 shows the most common gamma energies produced by the source[15].

Table 1: Common photon (gamma and *X-rays) energies produced by ^{241}Am

Source (Nuclide)	Energies, keV (photons per 100 disintegration)
^{241}Am	59.54 (35.92), 26.34 (2.31), 33.20 (0.12), *11.89-22.2 (37.66)

The movie was later processed frame by frame using the *LoG* function in scikit-image python library[16] to detect bright cluster of pixels or blobs and their respective coordinates. Further computations were carry out to obtain charge collection value by summing all pixel values for each blob. These charge collection values were then discriminated into bins or channels. The software tool for experimental control and details of data processing can be found in Ref[17].

RESULTS AND DISCUSSION

It is noteworthy to state that gamma photons can be detected only with the occurrence of ionizing event right at the midst of the CMOS capturing an image. The thin layer of the CMOS indicates that the probability of any ionizing event is very low as most gamma photons, especially the high energy ones, may just pass through the active semiconductor depletion region. The 241 Am source used with its relatively low energy gamma photons allowed higher ionizing event to be captured for better statistics. Figure 1 shows the webcam camera that was used whereas Figure 2 shows the measurement physical setup.

Figure 1: The webcam used for capturing ionizing events in a movie frame with the one wrapped in aluminum foil was used for experiment.

Figure 2: The experimental physical setup with the ^{241}Am source surrounded by lead bricks with opening only to the webcam.

Figure 3 shows an example of image obtained from summation of every frame in one measurement for source to detector distance of 5 cm. This summation wasdone to show the intensity of ionizing event as individual cluster of bright pixels. In truth each frame may just captured a couple of events. Figure 4 shows the LoG identification of these ionizing events which are represented with rings.

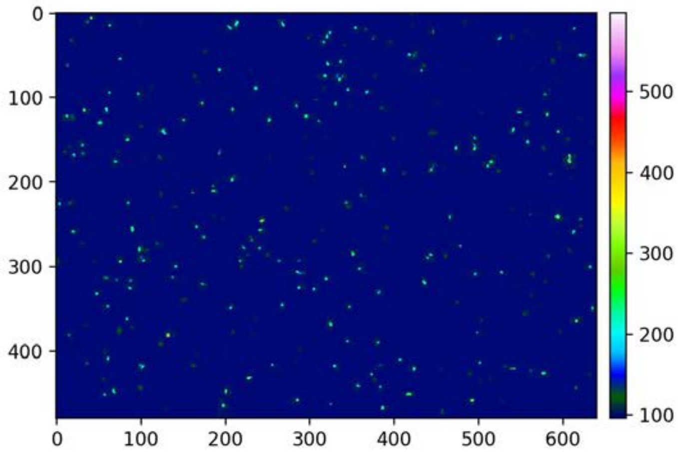

Figure 3: Summation of all ionizing events for a measurement at 5 cm source to detector distance.

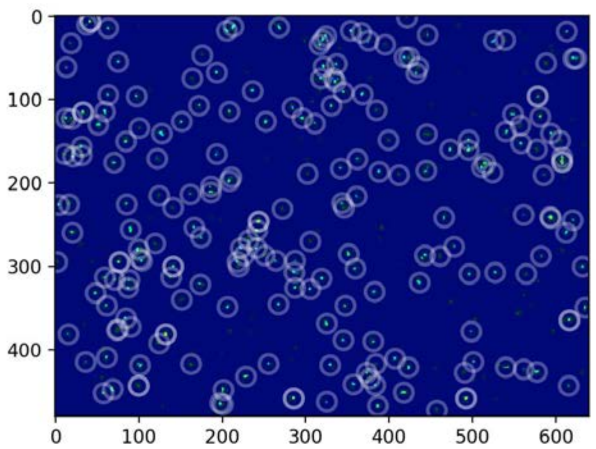

Figure 4: *LoG* identification of these ionizing events (shown as rings).

The output of LoG algorithm in scikit-image python library provides a list of image coordinates (center of rings as shown in Figure 4). In reference to these coordinates taken as center to an area, charge collection value was then calculated by summing all pixel intensities in the pixel area of 441 (21 x 21). This area is perceived to cover more than the observed area of bright pixels cluster caused by ionization event. This was based on our visual inspection as well as the maximum calculated area of 278. Summation value for all the bright pixels inside the cluster area which was then regarded as charge collection value. These values were then discriminated into channel of bins (charge collection value) to obtain a ^{241}Am spectrum for evaluation. Figure 5 shows the ^{241}Am spectra (stair plot) for each source to detector distances.

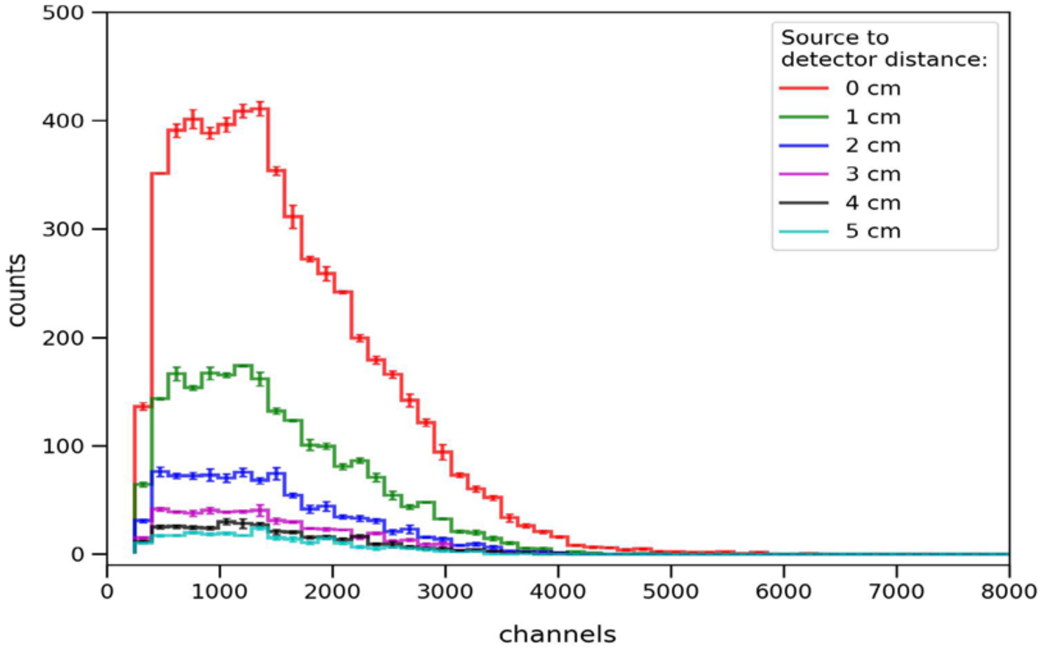

Figure 5: Spectra of ^{241}Am for each source to detector distance.

Two visible peaks can be discerned from spectra for 0 and 1 cm source to detector distances. These peaks are at around 700 and 1300 of charge collection value. At much larger source to detector distances, no discernible peaks can be seen because of insufficient ionization and thus poor statistics. These two peaks perhaps represent gamma energy at 59.5 and 11-22 keV (Table 1).

The thickness of the CMOS sensitive region is not a number that manufacturers of CMOS cameras usually provide. This sensitive region depth would probably in the region of few microns[4]. Such thin layer reduces the possibility of efficient energy deposition caused by ionizing event. Perhaps only small part of the energy deposited into CMOS translates to the charge collection value. Measurement of the energy spectrum is expected not possible for higher energy gammas. Nevertheless, good spectrum resolution has been shown possible for photons energy lower than 10 keV[18].

CONCLUSION

Identification and quantification of ionizing gamma events on CMOS sensor in a consumer webcam can be attained with *LoG* algorithm. Thereon, charge collection values can be computed and gamma spectrum can be build for the gamma source. CMOS from webcam however may not be able to discriminate the gamma spectrum efficaciously. This is because of the low energy deposition of ionizing event on the thin CMOS sensitive region. Increasing this energy deposition by introducing a layer of filter material above the CMOS can be explored to obtain better gamma spectrum.

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