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Utilization of Webcam Cameras as X-Ray Image Capture Based on kV Settings and Shutter Sensors

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ABSTRACT The end product of an x-ray image is often a sheet of film. The film must go through chemical processing in order to produce an image. To get around these issues, efforts were undertaken to create digital x-ray detectors utilizing far less expensive gadgets. The aim of this research is to present a study that explores the development of a digital X-ray imaging system using cost-effective sensors, assesses its image quality, and discusses the potential benefits of this technology for capturing X-rays.Utilizing sensors that try to determine the difference in the final image's quality as well as voltage variances. The system may present negative image findings from webcam camera captures that have already passed the image processing process with the Matrix Laboratory (MATLAB) Application, which is the study's main contribution. With a set mA of 25mA, a period of irradiation of 1 second, and a moderate intensity of illumination light, the measurement ranges employed are 60, 65, and 70 kV. Knowing the value of kv and optimal sensor settings based on image results is the study's goal. The measurement findings demonstrate that the Philip brand DR's picture results and those from the X-ray picture Capture Tool may be compared thanks to the MSE value of 34.8775 and the parameters Phototransistor BPT1331 at 70kV and 25mA. And the LDR, 66kV, 25mA configuration has the lowest MSE value at 61.7615. The study's findings suggest that the gadget can be used to record X-rays.

INDEX TERMS X-Ray, MATLAB, MSE

I. Introduction

X-Ry imaging has traditionally relied on film sheets for obtaining results. However, film-based X-rays come with certain limitations, such as the inability to easily edit the images and the presence of obstacles like excessive darkness, brightness, and noise in the results [1][2][3]. Digital X-ray machines enable image editing, allowing for adjustments to be made to enhance image quality. Furthermore, the images can be stored as a database, facilitating easy access and retrieval whenever required. They can also be conveniently printed or transmitted via local internet networks to a doctor's personal computer, enabling efficient analysis of a patient's condition. These capabilities make digital X-ray machines a significant advancement in medical technology [4][5][6]. Despite the advantages, one of the major drawbacks of digital X-ray machines is their high cost, making them inaccessible for some healthcare facilities. Additionally, the operation of these machines demands a significant investment in human resources for training and maintenance. [7]. These new digital X-ray devices employ voltage variations and sensors to assess and differentiate image quality. Factors such as tube voltage, time, and distance play a crucial role in determining the quality and quantity of the resulting images during the irradiation process. By utilizing these parameters and employing cost-effective technologies, researchers aim to create digital X-ray machines that are more affordable while maintaining acceptable image quality.[8][9] With these machines have prompted the development of cheaper alternatives. By leveraging voltage variations and sensor technology, researchers are striving to create more affordable digital X-ray devices without compromising image quality. These advancements hold great potential for expanding access to high-quality diagnostic imaging in healthcare settings.[10]

In 2015, Luiz Antonio P. dos Santos and his colleagues conducted a study on the comparison of phototransistors, ionization chambers, and photodiodes as x-ray beam dose detectors. According to him, the phototransistor sensor is the strongest candidate as a detector for x-ray diagnostic purposes because it has small dimensions, high output current, and does not require high voltages [11]. In 2021, Edrine

Damulira conducted research on comparing the performance of BPW34 photodiodes and cold white LEDs based on diagnostic X-Ray induced signals. According to BPW34 photodiode and cold white LED, the precision is 84.8% and 85.5% [12]. In 2016, Kusminarto conducted research on the development of a phototransistor-based X-ray detector BPT1331, according to which this type of phototransistor could be used for X-ray light sensors using darlington gain [13]. In 2016, Jawaaz Ahmad and Romana Yousuf conducted research on measuring low light intensity using a Light Dependent Resistor (LDR) sensor. According to him, the LDR sensor can be used as a sensor for this research [14]. P. Zhang conducted research on flat panel detectors which are intended as radiation gas detectors [15]. P. Bernhard, A. Brogna, S. Caiazza et al designed construction of large-area micro-pattern gaseous detectors [16]. In 2021 Yuanhong Gao, Yongshuai Ge, Xinwei Wang et al conducted research with the title Ultrathin and Ultrasensitive Direct X-ray Detector Based on Heterojunction Phototransistors in this study stated that Most contemporary X-ray detectors adopt device structures with non/low-gain energy conversion. Because of that, the research adopted a new high-gain device concept of a heterojunction X-ray phototransistor. In contrast to conventional detectors, X-ray phototransistors allow both electrical gating and photodoping for effective carrier-density modulation, leading to high photoconductive gain and low noise.[17]. In 2021, Gerald K. Ijemaru, Augustine O. and their friends investigated the analysis of imaging processes using Matlab. According to him, with Matlab, various steps used for image processing can be properly documented and replicated. And the Matlab-based image processing algorithm is more advanced than other advanced image processing applications [18]. Several other studies state that the MATLAB application is very possible to be used as an image processing application. In this case the use of MATLAB as grayscale image processing [19][20]. Several other studies conducted research on the use of digital radiography as a technology that is up-to-date and can be further developed in accordance with the times [21][22][23]. Ravneet Kaur, Ravtej Singh Sandhu, Ayush Gera, and Tarlochan Kaur conducted research on edge detection in digital panoramic dental radiograph using improved morphological gradient and MATLAB. This study focuses on automating edge detection of panoramic dental radiographs using the Multiple Morphological Gradient Method and making use of MATLAB for implementing algorithms developed. Datasets of digital panoramic dental radiographs in JPEG format are used for edge detection of the region of interest. The results show the successful implementation of the methodology developed [24]. In a 2020 study conducted at the UNNES medical physical laboratory, Susilo, Purwaningsih, Darsono et al explored the synchronization of a camera and X-ray tube in a digital radiography system. The researchers utilized a DSLR camera as the X-ray image capturer. However, the study highlighted certain challenges associated with using DSLR cameras, including their large dimensions that require significant space and the high cost, making them unaffordable for many. These limitations emphasize the need for more compact and cost-effective alternatives in digital radiography systems [25].

The research conducted highlights a significant gap in the study of digital detectors that rely on cameras and PCs for data processing. Although some research has been undertaken, the manufacturing costs associated with this technology remain relatively expensive. Consequently, there is a pressing need for continued exploration and development in this field to enhance accessibility and affordability. By addressing these challenges, researchers can pave the way for wider adoption of digital detectors, potentially unlocking their potential for various applications across industries such as surveillance, imaging, and scientific research.

Based on previous research, the author aims to utilize a webcam camera for capturing x-ray image results by varying the kV parameter setting and using four different interchangeable shutter sensors: PH101 Phototransistor, BPT1331 Phototransistor, BPW34 Photodiode, and LDR (light-dependent resistor) sensors. The goal is to achieve affordability while enabling the camera to capture images generated by screen fluorescence. Furthermore, Matlab will be employed for image processing to analyze the impact of the kV setting on the resulting grayscale. This research endeavor seeks to contribute valuable insights into the use of webcam cameras in x-ray imaging, potentially providing a cost-effective solution for medical and scientific applications. The aim of this research is to present a study that explores the development of a digital X-ray imaging system using cost-effective sensors, assesses its image quality, and discusses the potential benefits of this technology for capturing X-rays. The contribution of this study is as follows :

1.Development of the webcam camera captures that have previously passed the image processing process with the Matrix Laboratory (MATLAB) Application.
2. Use the PH101 phototransistor sensor, BPT1331 phototransistor, BPW34 photodiode, and LDR (Light Dependent Resistor) to trigger the camera
3. The study's main contribution is the development of the digital X-ray detection system and the methodology for capturing and processing X-ray images using affordable sensors and technology..

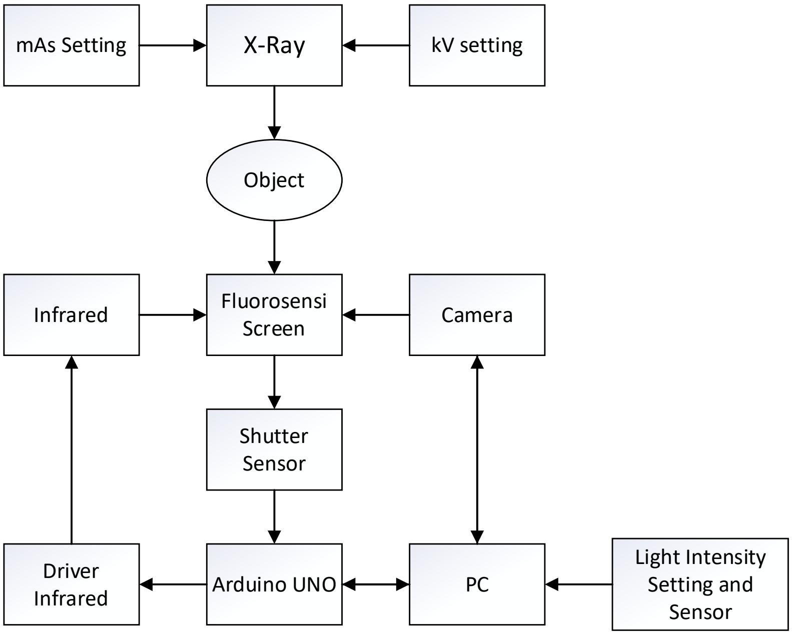

Figure 1 The Diagram Block

II. Materials And Methods

A. *Experimental Setup*

This study used Philips Digital Radiography as a producer of X-Rays. Data acuisition uses 3 types of kV, specifically 60 kV, 65 kV, and 70 kV with 4 sensors, specifically Phototransistor PH101, Phototransistor BPT1331, Photodiode BPW34, and LDR with the set mA setting of 25mA, irradiation time 1 second and the intensity of the lighting is medium.

1) Materials And Tool

This research uses fluorescence screen to convert X-Rays into visible light. Phototransistor PH101, Phototransistor BPT1331, Photodioda BPW34, and LDR as shutter sensors. Logitech webcam camera as image capture. Infrared to provide lighting for the camera. Arduino UNO as a microcontroller.

2) Experiment

In this study, after the design was completed, a test was carried out by comparing the MSE value of the processed image with the DR image. The object used in this study is a solid object, padlock. When carrying out data collection, the condition of the room must be dark and it is not permitted to turn on the lights. And also when carrying out data collection, the padlock is placed in the middle above the device that is directly opposite the digital x-ray window.

B. *The Diagram Block*

The tool system's block diagram is explained in FIGURE 1. In the mA, Second, kV, and X-Ray setting blocks, pieces of Philip's Computed Radiography (CR) radiography equipment are displayed. So a solid item is what is being employed in this beam. Then, in the infrared block, tools will be created for the screen fluorescence, camera, shutter sensor, infrared driver, arduino, PC, and infrared intensity settings and sensors. The mA must first be set to a specified value, and the kV must then be modified to a different value in the control table. The chosen infrared light intensity and shutter sensor are chosen on the personal computer. After the radiograph produces X-Rays, some of the rays are absorbed by the object and the remaining ones are transmitted to the screen where they are converted to visible light. The visible light from the screen is then captured by the shutter sensor and processed by the microcontroller to tell the infrared driver to turn on the infrared and also send a signal to the personal computer so that the camera can capture it. The camera's pictures will then be processed in Matlab.

C. *The Flowchart*

The detector's flowchart is shown in FIGURE 2. The shutter sensor detects the light when the object's screen fluorescence emits it, which causes the Arduino to be activated. The camera is then instructed by the Arduino to take a picture of the visible light emitted by the screen fluorescence, and the infrared sensor is also turned on to help with the picture-taking operation. The collected image is then sent to the PC to be processed there using the Matlab program. This process makes sure the right image is taken and makes it possible to analyze and manipulate the image data later. The Arduino, camera, and infrared technology combination enables a seamless and synchronized operation, improving the detection system's overall effectiveness and accuracy. This approach shows potential in a number of situations where it is important to capture and process images in visible light produced by screen fluorescence.

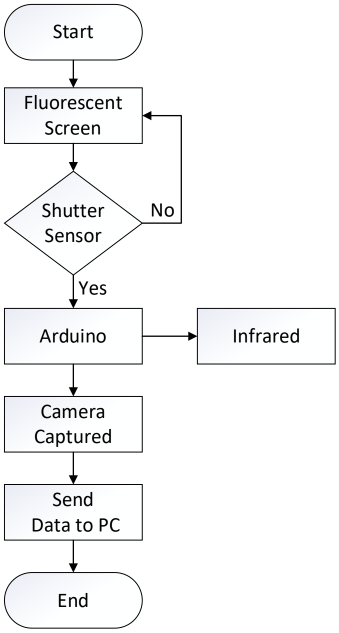

Figure 2 Flowchart of the detector

In **FIGURE 3** show the flowchart of the processing image. After the application is run and the program initialization occurs, Matlab will wait for the image data to be sent by the camera to Matlab. After the image is entered, then next is the image processing process where it will be converted into a gray image which will then be converted into a negative image then the next step is to calculate the MSE value by comparing the image from the tool and the image from the DR Philips brand to see the effect of the kV setting on image quality.

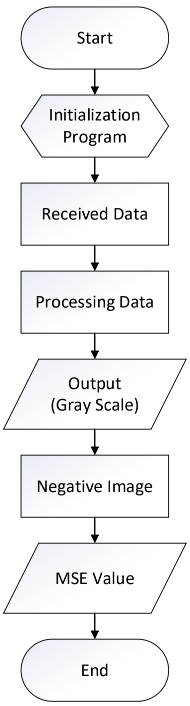

Figure 3 Flowchart of the processing image

D. System circuit

An important part of this development was the sensor circuit shown in **FIGURE 4**. This circuit functions as a shutter sensor for the camera so that it can capture the resulting X-Ray image.

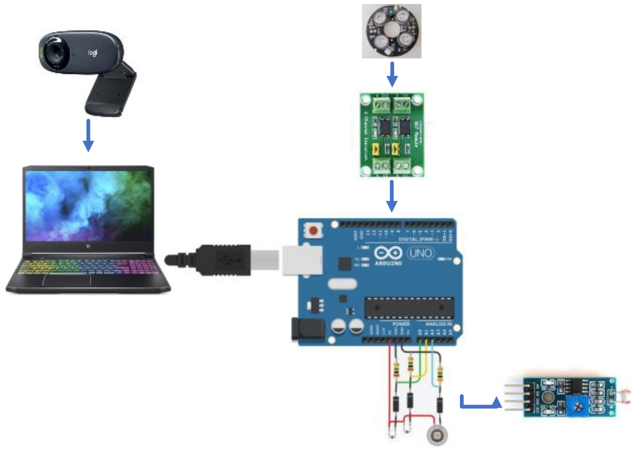

Figure 4 The sensor circuit

E. Data Analysis

The data analysis process involves interpreting the outcomes of data processing, specifically the results obtained from Matlab image processing. This analysis focuses on comparing the image outputs of different sensors, namely the PH101 Phototransistor sensor, BPT1331 Phototransistor sensor, BPW34 Photodiode sensor, and LDR (Light Dependent Resistor) sensor. The evaluation is based on the quality of the images using kV settings of 60, 65, and 70, with emphasis on the MSE (Mean Squared Error) value. A lower MSE value indicates superior image data quality. By examining and comparing these values, we can determine which sensor and kV setting produce the best image results. The formula for finding MSE (Mean squared error) is as follows eq (10):

$$\mathrm{MSE} = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left|\big(f(x,y)\big),-g(x,y)\big)^2\right| \quad (10)$$

From the formula above, the MSE value of the two images will be obtained, the smaller the MSE, the better the image quality.

III. Result

In this study, the X-Ray image capture tool has carried out a comparative test of MSE values using Philips brand digital radiography (DR) tools. Following are the results of the study:

Table 1
MSE value 60kV 25mA setting

MSE 60 kV, 25 mA	
BPT 60KV 25MA MEDIUM	59.4264 P²
BPW 60KV 25 MA MEDIUM	52.1168 P²
LDR 60KV 25MA MEDIUM	58.6278 P²
PH 60KV 25MA MEDIUM	59.0245 P²

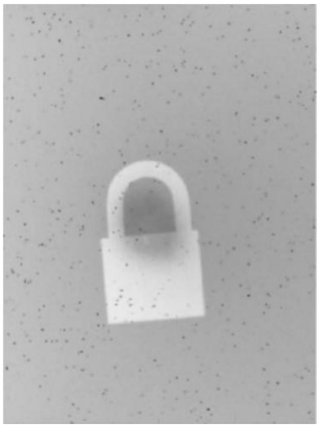

Figure 5 **BPW 60kV 25mA Medium**

TABLE 1 explains that there are results of the calculation of the MSE 60kV 25mA setting with medium intensity of illumination light. It can be seen that the smallest MSE value is the BPW sensor with a value of 52.1168. As we know that the smaller the MSE value, the better because it is similar to the image used as a comparison. The image results from BPW are shown in **FIGURE 5**. These results have already gone through the image processing process to become negative images in the MATLAB application.

Table 2
MSE value 66kV 25mA setting

MSE 66 kV, 25 mA	
BPT 66KV 25MA MEDIUM	51.0560 P²
BPW 66KV 25MA MEDIUM	60.4548 P²
LDR 66KV 25MA MEDIUM	61.7615 P²
PH 66KV 25MA MEDIUM	46.8958 P²

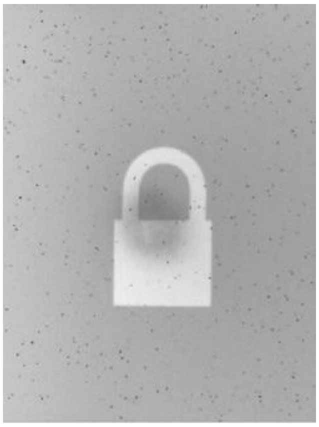

Figure 6 **PH 66kV 25mA Medium**

TABLE 2 explains that there are results of the calculation of the MSE 66kV 25mA setting with medium intensity of illumination light. It can be seen that the smallest MSE value is the PH sensor with a value of 46.8958. As we know that the smaller the MSE value, the better because it is similar to the image used as a comparison. The image results from PH shown in **FIGURE 6**. These results have already gone through the image processing process to become negative images in the MATLAB application.

Table 3
MSE value 70kV 25mA setting

MSE 70 kV, 25mA	
BPT 70KV 25MA MEDIUM	34.8775 P²
BPW 66KV 25MA MEDIUM	43.1454 P²
LDR 66KV 25MA MEDIUM	36.3903 P²
PH 66KV 25MA MEDIUM	47.8424 P²

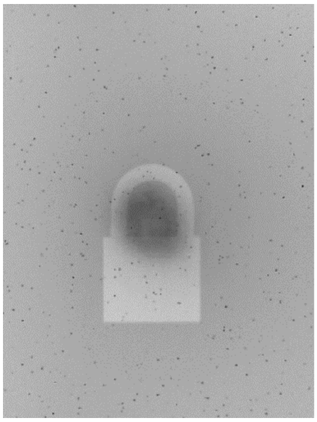

Figure 7 **BPT 70kV 25mA Medium**

TABLE 3 explains that there are results of the calculation of the MSE 70kV 25mA setting with medium intensity of illumination light. It can be seen that the smallest MSE value is the BPT sensor with a value of 34.8775. As we know that the smaller the MSE value, the better because it is similar to the image used as a comparison. The image results from BPT shown in **FIGURE 7**. These results have already gone through the image processing process to become negative images in the MATLAB application.

IV. Discussion

The measurement results from different X-ray settings of 60kV, 66kV, and 70kV exhibit varying Mean Squared Error (MSE) values. Through several data collection attempts, the following results were under the 60kV setting, the best MSE value achieved was 52.1168. This result was obtained using the Photodiode BPW34 sensor and a moderate light intensity setting. In the 66kV setting, the best MSE value recorded was 46.8958. The optimal result was obtained using the Phototransistor PH101 sensor and a moderate light intensity setting. When the X-ray setting was adjusted to 70kV, the best MSE value attained was 34.8775. The optimal result was obtained using the Phototransistor BPT1331 sensor and a moderate light intensity setting. Considering all the collected data, the best MSE value obtained was 34.8775. This result was achieved with a 70kV setting and 25mA, utilizing the BPT1331 Phototransistor sensor with moderate light intensity. These findings suggest that the combination of a higher X-ray setting, the appropriate sensor selection, and a moderate light intensity setting yields the most accurate and reliable results with the lowest MSE. Such information is valuable for optimizing X-ray measurements and ensuring high-quality imaging outcomes.

The measurement results from different X-ray settings, namely 60kV, 66kV, and 70kV, show varying Mean Squared Error (MSE) values. Through several attempts of data collection, the results were obtained under the 60kV setting, the best MSE value achieved was 52.1168. These results were obtained using a BPW34 Photodiode sensor and a moderate light intensity setting. At the 66kV setting, the best MSE value was recorded at 46.8958. Optimal results are obtained by using the Phototransistor PH101 sensor and setting the light intensity to medium. When the X-ray setting was adjusted to 70kV, the best MSE value achieved was 34.8775. Optimal results are obtained by using the Phototransistor BPT1331 sensor and setting the light intensity to medium. From all the data collected, the best MSE value was 34.8775. This result is achieved by setting 70kV and 25mA, utilizing the BPT1331 Phototransistor sensor with moderate light intensity. These findings show that the combination of higher X-ray settings, proper sensor selection, and moderate light intensity settings yields the most accurate and reliable results with the lowest MSE. This information is invaluable for optimizing X-ray measurements and ensuring high-quality imaging results.

The weakness of this study is that there is noise in the resulting image, which manifests as black spots that are scattered throughout the image area. These weaknesses hindered the overall quality and reliability of the study findings, indicating the need for further refinements and improvements in the image processing techniques used.

This research brings significant benefits to the wider community through the development of affordable digital detectors. By using a less expensive device, hospitals can reduce costs, enabling them to improve services and better serve the needs of the community. These innovations have great potential to improve the accessibility and overall quality of healthcare, ultimately benefiting the larger population.

V. Conclusion

In summary, this study aimed to develop an X-ray image capturing device using an Arduino-based webcam and MATLAB application. By investigating kV setting and shutter sensor parameters, the authors successfully created a system. Through observation, experimentation, and data measurement, it was determined that the PH101 phototransistor sensor, BPT1331 phototransistor, BPW34 photodiode, and LDR (Light Dependent Resistor) could trigger the camera. However, each sensor exhibited varying sensitivity due to differences in datasheets and circuits. This research provides valuable insights into sensor capabilities and informs future device improvements.

Among the 12 collected data points, the best image results were achieved with the 70kV 25mA setting, utilizing the BPT1331 Phototransistor sensor under moderate light intensity. This is supported by a low Mean Squared Error (MSE) value of 34.8775, indicating superior image quality in this configuration.

The hope for future research is to address several key areas. First, efforts will be directed at noise decomposition in image results to improve overall image quality. Additionally, there was a desire to optimize the capture time to achieve speeds under 1 second. Real-time image processing capabilities will be integrated for live analysis. In addition, reducing the error rate compared to Phillips brand DR tools is a priority. Finally, the device's wireless functionality will be expanded, enabling increased mobility and convenience in X-ray shooting.

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