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Modelling vision angles of optical camera zoom using image processing algorithm

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Abstract

A challenge of adding a new feature to the optical properties of a camera is solved in this paper. Image processing gives the possibility to enhance the quality, resolution and details of images fast these days. Within this paper, the introduced algorithm used to determine the vision angles (horizontal and vertical) of a digital camera (Nikon). The quality and efficiency of the camera are evaluated using determine the spatial resolution of the captured images. A scale factor algorithm is used also in this paper. A mathematical model introduced to describe the camera angle vision. This model works with different zoom degrees and different camera-object distances. Thus, a general mathematical equation obtained which describes the real image. The comparisons between the real and resulted images give a strong matching with small error rate.

Keywords: digital camera algorithm, scale factor, spatial resolution, field of view.

1. INTRODUCTION

In the old version of cameras, images are captured using chemicals on a tape then printed on photographic paper. Which means the process is a chemical reaction[1]. The presence of an electronic processor inside the camera can perform a lot of operations on the captured image, such as editing and deletion, and enables the recording of short video [2, 3].

A lot of studies regarding camera field of view are performed because it considered an important parameter in object detection [4,5] and field of view of satellite remote sensing instrument especially for instruments in space is changed where the comparison of dimensions revealed small differences [6]. The previous studies did not test the quality of cameras in terms of the capacity vertical and horizontal vision angles. Therefore, this study focused on determining horizontal and vertical angles (θ_h and θ_v), as shown in Fig.3, of a Nikon digital camera using different optical zoom degree (Z). Then estimate the best mathematical function to represent the relationship between the camera vision angles and the different object distances for different zoom degrees. Similar works were done previously, where the resulted data that computed from the introduced model could be compared[7]. The objective of this study is suggesting a mathematical model to estimate the vertical and horizontal vision angles for the digital camera by depending on known dimensions of an object. This model estimated by changing the optical zoom of the camera and the distance between the camera and the object. From this study, it is obvious there is a chance to add new information details to any camera specification.

2. CAMERA MAIN PARAMETERS

Different digital cameras have different sensor sizes. Width and height of the sensor are the keys to determine the vision field. A relation between sensor size and focal length determined the angle of vision (AOV) and field of vision (FOV). A wide angle of vision captures greater real areas, while the smaller angle covers smaller real areas. Camera vision angle can be changing by changing camera lens focal length [8, 9].



The vision field is the length that the lens will cover at a certain distance that can be classified into the angular field of vision (AFOV) exactly the same vision angle and linear field of vision (LFOV) unit of distance and requiring the knowledge of the distance from the lens to the subject [10].

Camera resolution can be defined as the ability of the optical system to record accurate details by distinguishing between two adjacent spatial, spectral, radiometric, and temporal signals. It also describes the details of the image. The higher the clarity, the more detail picture will be. Many discrete structures including vision, recording, and camera lenses each of which has an impact on the process of defining the resolution of the system. In addition to the environment that plays an important role in the process of photography [11, 12].

Camera zoom is the process of change (increased or decreased) the spatial resolution of the captured images. There are two camera zoom types; the first type is the optical zoom which changes image spatial resolution by changing the distance between the camera lens and the camera sensor. The second type is the digital camera zoom, where the spatial resolution changed by changed image size [13-15].

3. EXPERIMENTAL AND ALGORITHM

The camera vision angle represents a very important property of a camera. The camera vision angles at a constant zoom degree measured by calculating the scene object projected area in the 2D image plane. Where any zoom change in camera setting produces changing in the projected cover area for a real object in the image plane [9].

Camera angle or shooting angle is the angle of view of the scene that will be recorded or imaged. The study was based on the Nikon digital camera (D3200SLR) illustrated in Fig. 1, with its specifications listed in Table 1 [15].

Table 1: Nikon Camera Technical specifications [15]

Image device	24.2MP DX-Format CMOS Sensor
Image resolution	3008 x 2000 (6.0 MP, 3:2)
Focal length lens	Nikon AF-S DX 18-55mm f/3.5-5.6G VR Lens, 27 - 83 mm
International Standardization Organization (ISO) sensitivity	Auto, 100 - 6400 in steps of 1 EV; expandable to 12800
LCD screen	3" 921K-Dot LCD



Fig. 1: Nikon digital camera [15]

The Nikon digital camera used to study the mathematical model to be tested later to all types of digital cameras, because the details and specifications are well known and it is widely use. Hopefully, a new feature can be added to the characteristics of digital cameras.

In this study MATLAB software used to build algorithms that implemented within this paper. Also, table curve 2D (v.5.01) software used to determine the best fitting model. Fig.2 shows a mural painting (test image) with dimensions (9.7×13.5 cm) which placed orthogonal to the camera axis. The captured images, with resolution 24.2 Megapixel fixed, are recorded for different zoom degree (z) (18, 24, 35, 45, and 55 mm) at different distances (D=1m to 10 m), where the step size is 1m. Then estimate the dimension of the field of view in cm depending on calculating the dimension of the mural painting. Algorithm 1 converts the dimension from pixel to cm then finally to get vertical and horizontal vision angles (θ_v, θ_h).

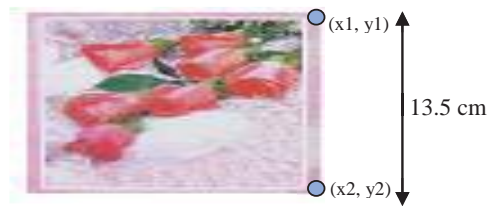


Fig. 1. : Represents a scene image (mural painting)

Algorithm: compute camera vision angles

Input

1. The captured image (img)
2. Input test image dimensions ($L_{\text{real}} = 13.5 \text{ cm}$) then select manually the top and bottom right corners ($x1, y1$) and ($x2, y2$), respectively.

Output

1. Object's length in pixel (L_{pixel})
2. The scale factor (SF)

Start Algorithm

1. Measure the length of the scene in pixels (length of the plane object) in image plane using a computer mouse by selecting points in the image plane ($x1, y1$) and ($x2, y2$) values between the ends of the plane object in the image, and compute length using:

$$L_p = \sqrt{(x2 - x1)^2 + (y2 - y1)^2} \quad (1)$$

2. Calculate the scale factor

$$SF = \frac{L_{\text{real}}(\text{cm})}{L_p(\text{pixel})} \quad (2)$$

3. Convert image dimensions (h and w) from pixels into centimetres using scale factor (SF):

$$H = SF \times h \quad (3a)$$

$$W = SF \times w \quad (3b)$$

4. Calculate vertical and horizontal vision angles based on the vertical and horizontal image dimensions at distance (D) for each zoom degree (Z) according to the following relationships:

$$\theta_h = 2 \times \tan^{-1} \left(\frac{H}{2D} \right) \quad (4a)$$

$$\theta_w = 2 \times \tan^{-1} \left(\frac{W}{2D} \right) \quad (4b)$$

Where D in eq. 's (4a and 4b) represent the distance between the cameras and the objects (θ_h and θ_w) as shown in Fig.3

End Algorithm

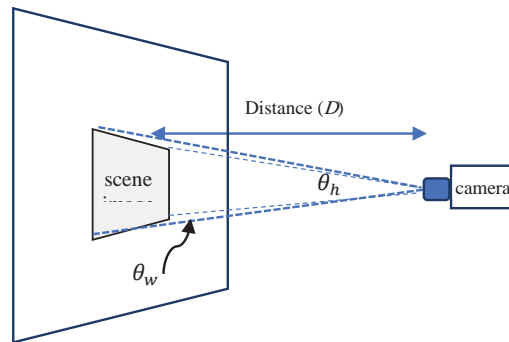


Fig. 2. : Angles of the camera vision for the mural image

4.RESULTS AND DISCUSSION

a. Results

Fig. 4 shows the camera vision angles (θ_w and θ_h) as a function of the zoom degree (Z) for different distances (D).

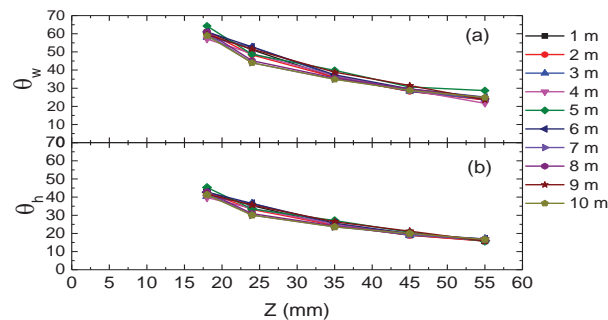


Fig. 3. The relationship between (Z) and (a) horizontal θ_h vision angle (b) vertical θ_w vision angle

Fig. (4) Shows that there is a decrease in the angle of view (θ_w and θ_h) with the increase of zoom degree (Z), i.e. camera vision angles have an inverse relationship with zoom (Z).

The relation between the ratio ($R = \theta_w/\theta_h$) and the zoom degree (Z) is extracted for different distances (D) as shown in Fig. (5). The behaviour of R is almost linear for all zooming values for different distances where the ratio is equal to 0.69 because the ratio between vertical and horizontal angle is the same for all cases.

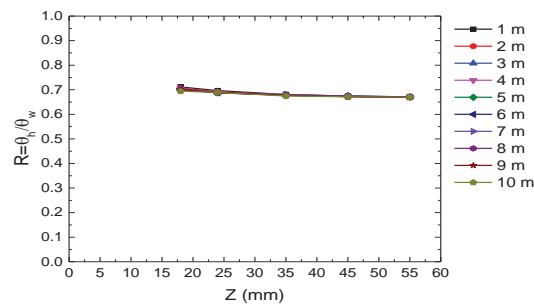


Fig. 4: Show the relationship between the ratio and zoom degree (Z)

Table (2 and 3) illustrate the values of the measured vision angles (θ_w and θ_h), respectively.

Table 2: The vertical camera vision angle (θ_w) for each zoom and at each distance (D)

$\begin{matrix} Z \text{ mm} \\ D \text{ m} \end{matrix}$	18	24	35	45	55
1	60.99	51.20	35.83	28.34	23.78
2	60.99	48.33	36.04	28.21	23.50
3	58.00	52.76	36.70	28.34	23.88
4	57.06	49.02	36.93	29.03	21.68
5	64.28	48.68	39.85	30.68	28.68
6	60.99	52.76	37.39	29.61	25.10
7	59.97	43.98	34.99	29.03	24.07
8	60.99	45.15	35.62	29.61	24.68
9	59.46	51.58	38.83	31.49	23.59
10	58.9	43.98	34.88	28.82	24.89
Average	60.17	48.75	36.71	29.32	26.58

Table 3: The horizontal camera vision angle (θ_h) for each zoom and at each distance (D)

$\begin{matrix} Z \text{ mm} \\ D \text{ m} \end{matrix}$	18	24	35	45	55
1	42.77	35.34	24.26	19.06	15.94
2	42.77	33.22	24.41	18.97	15.75
3	40.46	36.50	24.87	19.06	17.00
4	39.75	33.73	25.03	19.54	16.55
5	45.34	33.48	27.10	20.67	15.62
6	42.77	36.50	25.63	19.93	16.84
7	41.97	30.06	23.67	19.54	16.14
8	42.77	30.90	24.10	19.93	16.55
9	41.59	35.62	26.38	21.23	15.81
10	41.21	30.06	23.59	19.93	16.69
Average	42.14	33.54	24.88	19.73	16.19

b. Estimated model

The results in different zoom degrees and different distances fitted using two-dimensional table curve software to obtain the best mathematical model suitable for measuring the vision angles. The best fitting equation between camera vision angles and zoom degree (Z):

$$\theta_i = a_i + \frac{b_i}{Z} \quad (5)$$

where θ_i is vision angle, a_i and b_i are constants determined by the type of utilized digital camera, i is h or w .

The resulted data that computed from the introduced model compared [7] where the parameters are different according to the camera model, but the main model is the same.

The Inverse proportionality between vertical viewing angles (θ_w and θ_h) and the zoom degree (Z), for each distance and at each distance value (D) as shown in Fig. (6) and Fig. (7).

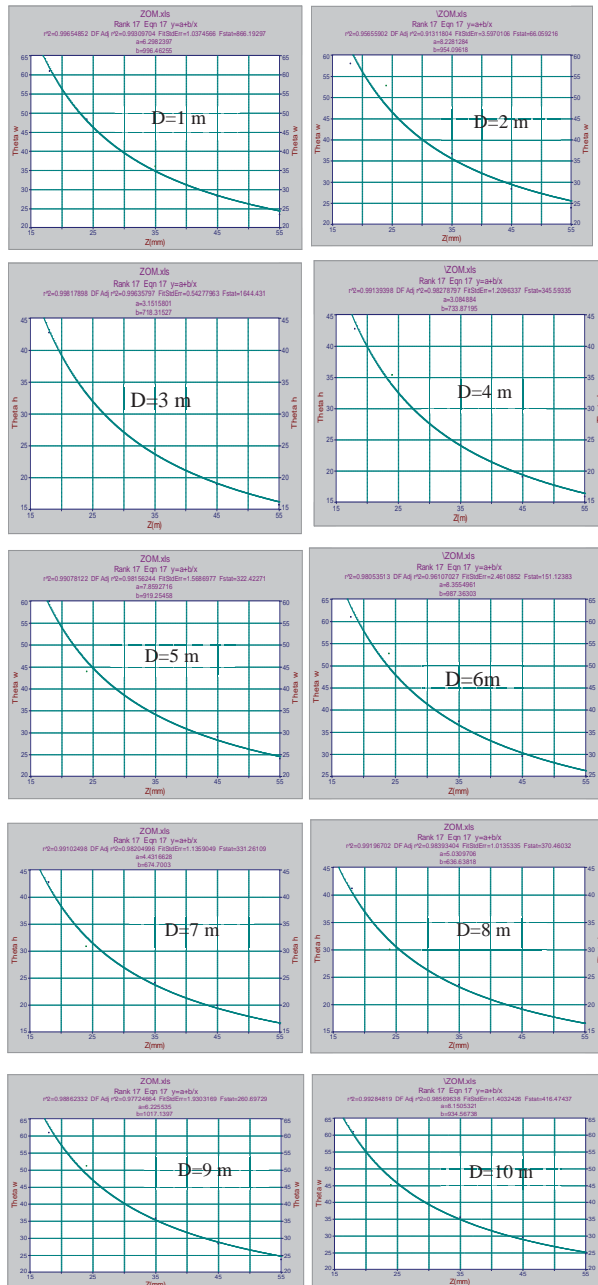


Fig. 4. shows the inverse proportionality of the angle of the camera vision (w) with the Z degree for different distances (D) for the Nikon camera

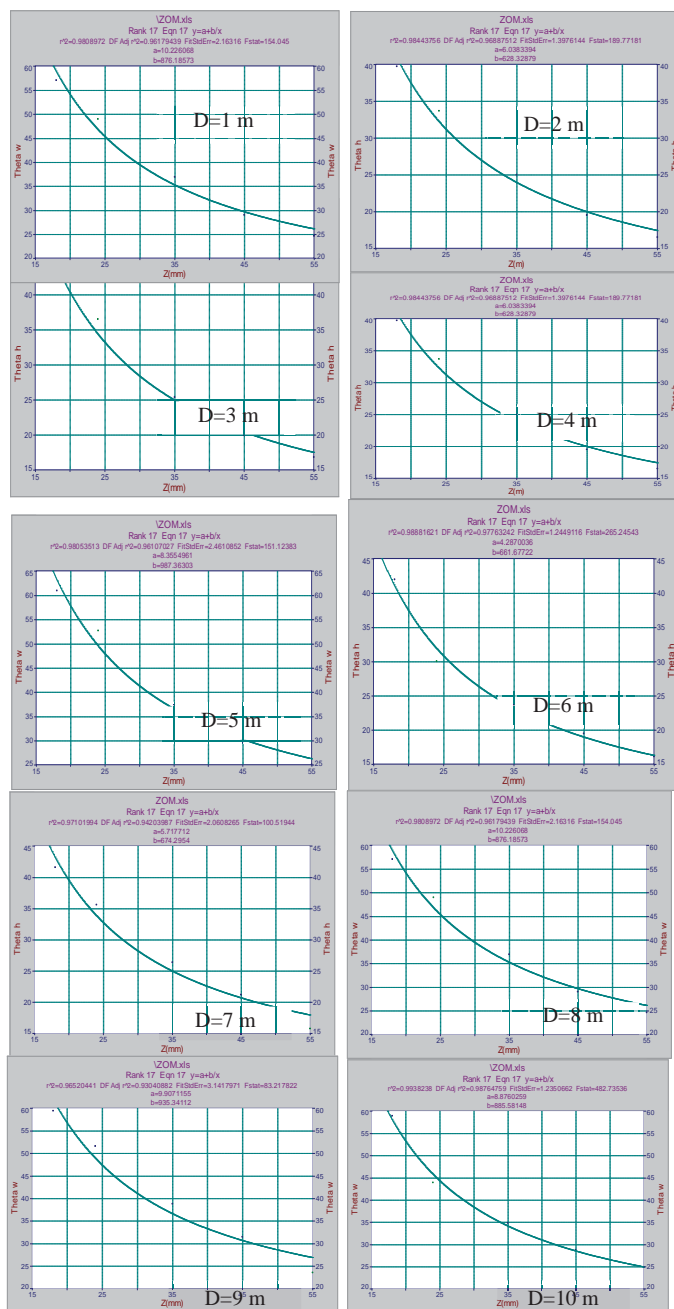


Fig. 5. shows the inverse proportionality of the angle of the camera vision (H) with the Z degree for different distances (D) for the Nikon camera

A built-in function fitting curves, from software table curve, extracts the fitting coefficients (a_i and b_i) in Fig. (6 and 7). The correlation value (r^2) between the data and their fitting curves are tabled in (4 and 5) for vertical and

horizontal vision angles, respectively, for different distances (D). The average values for fitting coefficients (a_i) and (b_i) are mentioned at the end of the table.

Table 4: The constant coefficients (a_i, b_i) of the vertical camera angle (θ_w) for each distance (D)

Constant Coefficient D m	a_w	a_w	r^2
1	6.225	1017.130	0.999
2	6.298	996.400	0.999
3	8.220	954.000	0.996
4	10.220	876.180	0.993
5	9.960	1008.000	0.999
6	8.355	987.363	0.993
7	7.859	919.250	0.997
8	8.150	934.560	0.995
9	9.907	935.340	0.992
10	8.870	885.580	0.994
Average	8.400	951.380	

Table 5: The constant coefficients (a_i, b_i) of the horizontal camera angle (θ_h) for each distance (D)

Constant Coefficient D m	a_h	b_h	r^2
1	3.08	733.87	0.998
2	3.15	718.31	0.999
3	6.03	628.33	0.995
4	6.98	630.48	0.994
5	4.37	635.20	0.999
6	4.54	714.16	0.994
7	4.28	661.67	0.996
8	4.43	674.70	0.994
9	5.71	674.29	0.993
10	3.08	636.63	0.992
Average	4.56	674.76	

Then used these values to determine the best fitting models, as follows:

$$\theta_w = \bar{a}_w + \frac{\bar{b}_w}{z} \quad (6)$$

$$\theta_w = 1.45 + \frac{951.38}{z} \quad (7)$$

$$\theta_h = \bar{a}_h + \frac{\bar{b}_h}{z} \quad (8)$$

$$\theta_h = 4.56 + \frac{674.76}{z} \quad (9)$$

Table (6, 7) illustrate the values of measured vision angles (θ_{we} and θ_{he}) from empirical models calculated according to equations (7 and 9) respectively.

Table 6: The vertical camera vision angle(θ_{we}) for each zoom and at each distance

Constant Coefficient D m	18	24	35	45	55
1	62.73	48.600	35.28	28.827	24.71
2	61.653	47.814	34.766	28.440	24.41
3	61.220	47.970	35.477	29.420	25.56
4	58.896	46.727	35.253	29.690	26.15
5	65.960	51.960	38.760	32.360	28.28
6	63.208	49.495	36.560	30.296	26.307
7	58.920	46.160	34.123	28.2867	24.572
8	60.070	47.090	34.850	28.910	25.140
9	61.870	48.879	36.630	30.690	26.910
10	58.060	45.760	34.172	28.549	24.970
Average	62.730	48.600	35.280	28.827	24.710

Table 7: The horizontal camera vision angle(θ_{he}) for each zoom and at each distance

$\begin{matrix} Z \text{ mm} \\ D \text{ m} \end{matrix}$	18	24	35	45	55
1	43.85	33.66	24.05	19.39	16.42
2	43.05	33.07	23.67	19.11	16.21
3	40.93	32.21	23.98	19.99	17.45
4	42.00	33.25	24.99	20.99	18.44
5	45.65	30.83	26.51	18.48	15.91
6	44.21	34.29	24.94	20.41	17.52
7	41.03	31.84	23.18	18.98	16.31
8	41.91	32.54	23.70	19.42	16.69
9	43.17	33.80	24.97	20.69	15.96
10	38.45	29.61	21.27	17.23	14.65
	43.85	33.66	24.05	19.39	16.42

The resulted two empirical models (θ_{we} and θ_{he}) have been tested for different D and Z values to compute camera vision angles from equation (7 and 9), respectively. The comparison between the real practical values (θ_w and θ_h) and the estimated values (θ_{we} and θ_{he}) is achieved. The results of comparison are shown in tables (8 and 9), and indicate a good agreement between real and estimated values with low absolute errors value can be noted. Therefore, the introduced method depends on a mathematical background and matches the real world dimensions. The difficulty is matching the shooting angles of the used camera and understands how it works and designs a model.

Table 8: Comparison between (θ_w) theoretically and practically, and calculate the proportion of error between them at distances (D)

D (m)	Z (mm)	θ_w	θ_{we}	Absolute error %
1	18	60.99	62.73	2
	24	51.20	48.60	5
	35	35.83	35.28	1
	45	28.34	28.83	1
	55	23.78	24.71	3
3	18	58.00	61.22	5
	24	52.76	47.97	9
	35	36.70	30.48	3
	45	28.34	29.42	3
	55	23.88	20.06	12
5	18	64.28	60.96	2
	24	48.68	01.96	6
	35	39.85	38.76	2
	45	30.68	32.36	5
	55	28.68	28.28	1
7	18	59.97	08.92	1
	24	43.98	46.16	4
	35	34.99	34.12	2
	45	29.03	28.28	2
	55	24.07	24.07	2
9	18	59.46	61.87	3
	24	51.58	48.88	5
	35	38.83	36.63	6
	45	31.49	30.69	2
	55	26.59	26.91	1

Table 9: Compression between (Θ_H) theoretically and practically, and calculate the proportion of error between them at distances (D)

D (m)	Z (mm)	Θ_h	Θ_{he}	Absolute error %
1	18	42.77	43.85	2.0
	24	35.34	33.66	4.0
	35	24.26	24.05	0.8
	45	19.06	19.39	1.0
	55	15.94	16.42	2.0
3	18	40.46	40.93	1.0
	24	36.50	32.21	13.0
	35	24.87	23.98	3.0
	45	19.06	19.99	4.0
	55	17.00	17.45	2.0
5	18	45.35	45.65	0.6
	24	33.48	30.83	8.0
	35	27.10	26.51	2.0
	45	20.67	18.48	11.0
	55	15.62	15.91	1.0
7	18	41.97	41.03	2.0
	24	30.06	31.84	5.0
	35	23.67	23.18	2.0
	45	19.54	18.98	2.0
	55	16.14	16.31	1.0
9	18	41.59	43.17	3.0
	24	35.62	33.80	5.0
	35	26.38	24.97	5.0
	45	21.23	20.69	2.0
	55	15.81	15.96	0.9

5.CONCLUSION

The modelling of the vision angles and its relationship with the different optical zoom is achieved using an image processing algorithm. The resulted mathematical model can be used for different type of camera. But the only difference will be the parameters a and b only. These parameters can be estimated easily for different optical zoom and different distance from the camera and the test image. The ratio between θ_w and θ_H ($R \approx 0.69$) is constant for a long range of distances (D) and zoom degree (Z), which means that this feature represents one of the parameters that can be depended for Nikon camera. As a result, it is one of a good way to determine camera quality or specifications. It is now possible to know this feature for this type or other types of camera.

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