

Visual Computing of Attributes of Geometric Solids using Color Queuing Theory and Evaluation of the Computed Values using Conventional Methods Based on Principles of Orthographic Projections

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Abstract

Literature review revealed that, “Color Queuing Theory” (CQT) was applied for analyzing the variation of color intensity of surfaces of moving objects, studying the surface texture of solids etc. An attempt is made in this paper to investigate the application of CQT for Visual Computing (VC) of attributes of Geometric Solids like straight lines, planes, solids etc and its Engineering Applications. The computed values obtained under the current method and the corresponding values obtained under the conventional method using the theoretical values to investigate the effectiveness of the current method.

Keywords: Color Queuing Theory, Dynamic objects, Attributes, Orthographic Projections, Visual Computing.

1. Introduction

The proposed method of Visual Computing of Depth [13] is based on the principle of “Color Queuing Theory”. This principle states that, the color intensity (pixel value) of the surface of an object gets faded away as the surface moves farther away from the observer. It ultimately gets merged with distant back ground color. The range of variation for pixel values for each component of RGB is between 0 and 255 [5].

Though discrete references were made in the literature on the applications of CQT [14] for VC of attributes like surface texture of solids etc [7,1], no work was reported on the application of CQT for VC of attributes of Geometric solids to address issues relating to Engineering Graphics (EG) [2], issues relating to the depth perception by Robots [8] etc. The accurate movements of Robots along and about the various degrees of freedom [8], essentially depend on how accurately the Robot has sensed the values of various attributes of the objects with which it is negotiating during its motion. Inbuilt sensors can be designed and developed in Robots for proper sensing of the various attributes of the solids surrounding the Robot [8]. References are made in the literature on the application of perspective projections [12] for computing attributes like depth [9] for interfacing with Robots. But a high degree of non-linearity existed between the actual depth values and the corresponding computed values, especially when the object is nearer to the projection planes. The current method of VC of attributes offers a satisfactory solution for addressing the above issues including its application in Engineering Graphics.

2. Present work

The present work pertains to VC of the following Geometric attributes using CQT.

- (1) Inclination of straight lines with predefined reference planes like horizontal and vertical planes (which are perpendicular to each other),
- (2) Angle between straight lines,
- (3) Distance between parallel straight lines,
- (4) Angle between skewed lines,
- (5) Inclinations of planes with predefined Horizontal and vertical planes,
- (6) Angle between planes,
- (7) Distance between planes,
- (8) Inclinations of axes of solids with predefined horizontal plane and vertical planes,
- (9) Inclination of surfaces of solids with the predefined horizontal and vertical planes,
- (10) Dihedral angles of solid.

The corresponding values of attributes using conventional methods are reported [3]. The theoretical values using Trigonometrical relations are also reported. The results of the current method and the conventional method are compared with the theoretical values to investigate the effectiveness of the current method. The various results are presented and discussed. The conclusions drawn, based on the above results are listed. The references are added at the end.

3. Methodology

Any 2D/3D object is supposed to be made up of a summation of infinite number of straight lines (SL) spread over their surfaces [6]. Hence, the VC of attributes 5 to 9, as referred to in Introduction, essentially consists of, analyzing the inclinations of the various (SL) constituting the given solid / surface [10,11]. The VC of inclinations of SL with predefined Horizontal Plane (HP) and Vertical Plane (VP) is dealt in detail and the findings are applied for the VC of various other attributes relating to planes and solids (attributes 5 to 10).

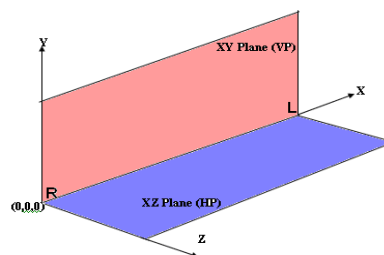


Figure 1. Pictorial Representation of XY Plane (VP) and XZ Plane (HP)

The conventional method of obtaining attributes (1 to 10) using the principles of (OP) [3] makes use of a 3D environment simulated on a 2D plane by using Orthographic Projections on XZ plane (HP) & on XY plane (VP) (Refer Fig 1). Both Hp and VP are shown on a single

plane separated by the line of intersection (RL) of HP and VP. The various attributes are measured with the help of Graphic Instruments.

The above referred attributes can also be computed using CQT.

Consider a line AB of length L kept parallel to both HP & VP (Fig 2 may be referred) using a high resolution Digital Camera, the image of the line is captured and sent to the computer.

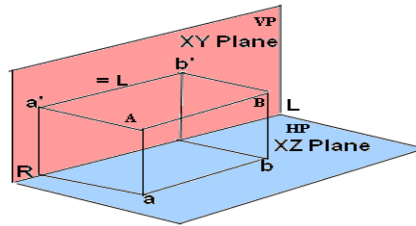


Figure 2. Pictorial view of a line AB parallel to both HP and VP

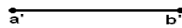


Figure 3. Acquired image of line AB ($a'b'$)

Referring to Fig 3, let the acquired image of line AB be $a'b'$. For distances between line AB and observer, (camera lens) more than 20 times the length of the line (L), the visual rays can be assumed to be parallel to each other [3]. Since line AB is parallel to VP, the length of the acquired image of the line $a'b' = L$. The pixel color intensity at various points on the line $a'b'$ is measured. For ease of measurement the image is taken in gray color.

Since all these points are equidistant from the observer [3] the pixel gray intensity at all points is same.

Let p_a represent the pixel value at end A

Let p_b represent the pixel value at end B

Let $\Delta p = p_b - p_a$

For the line AB, referred above $\Delta p = 0$. (Since points B and A are equidistant from the observer).

Fixing end A and keeping the line AB parallel to HP, let the end B, moved towards VP and take the position B. Let the line AB make an inclination of n degrees with VP (Refer Fig 4). Again the acquired image of this line is obtained as $a'b'$ (Ref Fig 5). Let length $a'b' = 1$. The pixel color intensity at B and A are measured and Δp is computed.

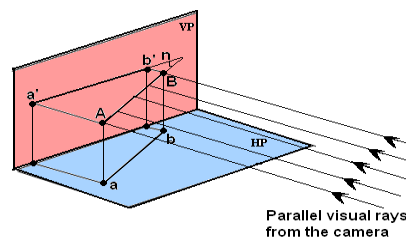


Figure 4. Pictorial view of line AB, parallel to HP and inclined to VP



Figure 5. Acquired image of line AB (a'b')

By generating data for various known values of n (inclination of line AB, with VP), the corresponding acquired image length l and Δp are tabulated. (Table 1)

Table 1. Gives the variation of Δp and l with inclination n at a given light intensity (7.00 am) for a given length L of the line AB.

Sl.No	n deg	$\tan n$	L (m)	l (m)	P_b	P_a	$\Delta p = P_b - P_a$
1	0	0.00	1.00	1.00	30	30	0.00
2	10	0.18	1.00	0.98	47	30	17.00
3	20	0.36	1.00	0.94	64	30	34.00
4	30	0.58	1.00	0.87	80	30	50.00
5	40	0.84	1.00	0.77	94	30	64.00
6	50	1.20	1.00	0.64	107	30	77.00
7	60	1.73	1.00	0.50	117	30	87.00
8	70	2.75	1.00	0.34	124	30	94.00
9	80	5.67	1.00	0.17	129	30	99.00
10	90	-----	1.00	0.00	----	30	-----

The acquired images of lines for different values of n are shown in Fig 6. The procedure is repeated at different light intensities from 700 am to 8.00 pm and the effect of light intensity on Δp is tabulated in Table 2.

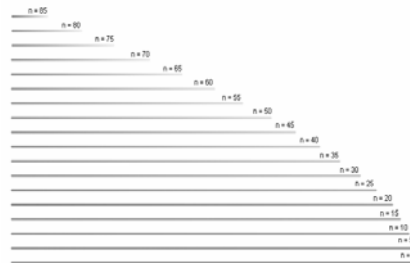


Figure 6. Trimmed and arranged acquired lines for a given L and for different values of n at a given light intensity (7.00 am)

Table 2. Δp values at different light intensities

l	l	n	$\tan n$	a	b	c	d	e	$\Delta p / l$
1	1	0	0						0
0	0	0	0	0	0	0	0	0	0.00
0	0	1	0	7	8	7	6	7	7.3

	8		8							5
	0		0							3
	.9	2	.3							7.2
	4	0	6	4	6	5	3	5	5	3
	0		0							5
	.8	3	.5							8.6
	7	0	8	0	2	1	9	1	1	2
	0		0							8
	.7	4	.8							3.1
	7	0	4	4	5	3	3	4	4	2
	0		1							1
	.6	5	.2							21.
	4	0	0	7	8	9	8	8	8	88
	0		1							1
	.5	6	.7							68.
	0	0	3	7	0	0	6	4	4	00
	0		2							2
	.3	7	.7							79.
	4	0	5	4	6	6	3	5	5	41
	0		5							5
	.1	8	.6							88.
	7	0	7	9	1	01	8	00	0	24
	0									
	.0	9								
0	0	0	*	*	*	*	*	*	*	*

Column [a] corresponds to Δp values at 7.00 am (Scattered light)

Column [b] corresponds to Δp values at 10.00 am (Direct Sun light)

Column [c] corresponds to Δp values at 2.00 pm (Direct Sun light)

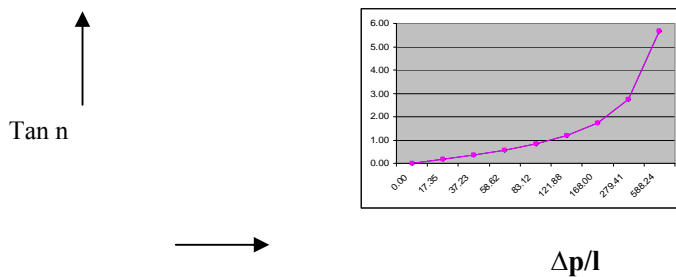
Column [d] corresponds to Δp values at 4.00 pm (Direct Sun light)

Column [e] corresponds to Δp values at 8.00 pm (Fluorescent light)

Column [f] corresponds to average Δp values.

The variation of $\Delta p/l$ with $\tan n$ is plotted in Graph 1. A second order equation (Equation 1) using the method of least squares [4] is proposed to compute the value of $\tan n$ in the form $\tan n$ (Computed) = $C_0 + C_1 \Delta p/l + C_2 (\Delta p/l)^2 \rightarrow \text{Eq1}$

Where C_0, C_1 & C_2 are constants and are tabulated in Table 3.



Graph 1. Graph between $\Delta p/l$ and $\tan n$

Sl.No	Constant	Value
1	C ₀	-0.004703
2	C ₁	0.010193
3	C ₂	-0.000001

Table 3: Constants for Equation 1

Using equation 1 the value of Tan n is computed for different values of Δp/l and the computed value of n is reported as n computed using CQT = $\tan^{-1} [C_0 + C_1 \Delta p/l + C_2 (\Delta p/l)^2]$ → Eq2

Using the conventional methods of orthographic projections, the values of n corresponding to the values of l used in equation 2 are measured and reported as n computed under conventional method.

Theoretical values of n for the same l values used in Equation 2 are computed as n theoretical = $\cos^{-1}(l/L)$ → Eq3

Table 4 gives the values of n theoretical, n computed under current method and n computed under conventional method. Also seen in Table 4 are the % deviations of n computed under current method from n theoretical and n computed under conventional method from n theoretical.

Table 4. Deviation of n computed from n theoretical

Sl.No	L (m)	l (m)	a	b	c	d	e
1	1.0	1.00	0	0.00	0.00	0.00	0.0000
2	1.0	0.98	10	9.85	1.50	10.00	0.0000
3	1.0	0.94	20	19.9	0.50	20.30	1.5000
4	1.0	0.87	30	30.1	0.33	30.40	1.3333
5	1.0	0.77	40	40.2	0.50	39.87	-0.3250
6	1.0	0.64	50	50.3	0.60	50.70	1.4000
7	1.0	0.50	60	59.6	0.67	59.23	-1.2833
8	1.0	0.34	70	70.9	1.29	70.10	0.1429
9	1.0	0.17	80	79.6	0.50	79.95	-0.0625
10	1.0	0.00	90	90.0	0.00	90.00	0.0000

Column [a] corresponds to theoretical values of n.

Column [b] corresponds to values of n computed using conventional method.

Column [c] corresponds to % deviation of n computed using conventional method from theoretical values of n .

Column [d] corresponds to values of n computed using CQT.

Column [e] corresponds to % deviation of n computed using CQT from theoretical values of n .

From Table 4 it is seen that the percent variation of n conventional from n theoretical is from 1.3 to -1.5, where as the percent variation of n using CQT from n theoretical is from 1.5 to -1.2.

Equation 1 can also be used for computing depth between ends A & B of a line AB as shown below.

$\tan n \text{ computed} = d/l$ & hence $d = l \tan n$.

Where d is the difference in depth between ends B and A of a straight line AB and l is the length of the corresponding acquired line.

This analysis can be extended for computing angles between two lines, distance between parallel straight lines, and angle between skewed lines by considering the respective lines (attributes 2, 3, & 4)

In respect of other attributes the above analogy can be extended.

4. Results and discussion

1. Application CQT is mostly confined to 3DV through color shading, studying surface texture of solids, speed of moving objects through color intensity variation etc [1, 5, 6]. Specific application of CQT for addressing issues relating to attributes of geometric solids as mentioned in the present work is not reported in literature.

2. As seen from Table 4, the percent variation of computed values of n under current method using CQT from theoretical values is within 1.5 to -1.2 percent.

3. As seen from Table 4, the percent variation of computed values of n under conventional method using principles of orthographic projection from the theoretical values is from 1.3 to -1.5.

4. An interesting observation from table 2 reveals that, the value of Δp for a given value of n almost remained constant irrespective of the nature of light.

5. Results 2 and 3 indicate that computed values of attributes under current method very well compare with the theoretical values and values computed under conventional method.

6. The variation as reported in Result 2 may be attributed, due to the fact that, there can be a small error in reading the pixel intensity values at different points along the length of the acquired lines.

7. The distance between the line and the observer (Digital Camera Lens) is chosen as 20 times the actual length of the line, in order that the viewing rays from the eye of the observer are parallel.

8. Since the percent variation of n computed using CQT is from 1.5 to -1.2 of theoretical value, this method can be used for addressing issues relating to attributes of Geometric solids in Computer graphics.

9. Through suitably written algorithms the current method can be interfaced with Robots for their depth perception, enabling them to execute more accurate movements.

10. By making suitable assumptions and modifications, the current method can form a powerful tool in Technography.

11. The proposed method offers a good substitution for solving problems on Engg Graphics, there by eliminating the tedious methods involved in Engg Graphics using conventional methods.

12. The reliability of the computed attributes largely depends on the accuracy with which the pixel values are read. Hence, lot of care was taken throughout the investigation, for accurately measuring the values. At the point of interest, 4 or 5 pixel values are read and the average value is considered as final.

5. Conclusions

1. The major findings based on the result reveal that the value of attributes computed using CQT, very well compare with the theoretical values. Hence, the current method can be used as a powerful tool for addressing issues relating to Engg Graphics and issues relating to depth perception by Robots.

2. Apart from using the current method for addressing issues relating to Engineering Graphics as future work, its application can be extended to the areas of computer Integrated Manufacturing (CIM), Spatial visualization of solids, mathematical programming for Rapid Manufacturing, Satellite Map reading, Rapid Prototyping (RPT) etc.

3. Another important area for future work using the current method is, to develop suitable tools for applications in Technography.

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