

Fusion for Multiple Light Sources in Texture Mapping Object

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Abstract—In this paper, fusion method using wavelet transform was used to calculate the effects of multiple sources of light to make the object look more realistic and more informative than the original parts which take the effect of each light source alone. The color value of any pixel in the object depends essentially on the color of the specific mapped texture as well as on the effect of the light sources that produce bright or dark pixels value depending on the distance between the pixel and light source and the direction of light rays. The proposed method merges the effect of multiple lights. Instead of summing these effects, the method takes from each pixel one of three conditions. These states are the maximum effect among all sources of the light, the minimum effect among all sources to reflect fine shadow and the ratio effect from all sources. This ratio depends on the relative parameters among all sources.

Index Terms—Fusion; Light Sources; Realism; Texture Mapping.

I. INTRODUCTION

A 3D model is a mathematical representation of a physical entity that occupies space or a description of its shape. The main methods of 3D object's representation are: -

- Boundary-based (b-rep): the surface of the 3D object is represented. Polygon meshes, which are common representations of this type, divide a continuous surface in polygonal cells, such as triangles, quadrilaterals, etc. [14].
- Volume-based: the volume of the 3D object is represented. Voxels and Constructive Solid Geometry (CSG) are commonly used to construct volumetric shape using the primitives [9].

Texture mapping is a technique that used to make 3D objects and scenes look real. It is done by adding fine surface properties on an object, like color, specularities, bumps, shadow, and other effects, which lead to more realistic objects and make a scene looks real. A texture is a raster image, and its pixels, called texels shorten the texture elements. A position in a texture is referred and specified by texture coordinates (UV-coordinates) [13], Texture-mapping methods can be summarized into:

- 1) Nearest neighbor Texture Mapping: This method changes the pixel's screen coordinates by texture coordinates and copies the value of the closest Texel [9].
- 2) Linear (Affine) Texture Mapping: It finds the texture coordinates for each vertex. The vertices are then used as a guide in the texture image to find linearly the suitable related color values for all points inside the polygon [10].
- 3) Bilinear Texture Mapping: Bilinear mapping is done

by applying two successive separated linear interpolation operations [9].

- 4) Projective (Perspective) Texture Mapping: The projection from one plane through a point to another plane is performed, where a texture is projected onto object surfaces [10][13].

Bump mapping is a technique in computer graphics for simulating bumps and wrinkles on the surface of an object. This operation is achieved by changing and perturbing the normal of the surface in the object and using the changed normal during lighting calculations [10].

Barycentric Coordinate Interpolation is an important and essential tool for dealing with triangle mesh, barycenter, meaning center of gravity. Barycentric coordinate examine the point in specific triangle and apply linear interpolation over a triangle. Barycentric coordinates of any point in triangle can be calculated as a ratio of the triangle areas [15]. One important useful property of barycentric coordinate is that if there are two triangles in different spaces, each point in one triangle shares the same barycentric coordinates with another point in the other triangle, in spite of the differences in vertices [10].

Lights present the source for illuminating of the objects and scenes in a virtual world. There are typically four types of lights in graphics systems

- 1) Ambient: The type of light that is uniformed in all directions and locations [14].
- 2) Directional: It has a direction where all light rays pass through this direction, but this type of light does not have a specific location [13].
- 3) Point: This type of light has a location in the virtual world and graphics environment. It sends out the rays of lights in all directions [9].
- 4) Spotlight: It is similar to a point light, but its directions are restricted in a specific direction [13].

As the angle of illumination between the light rays and surface normal moves away from the surface normal, the illumination of the point drops off. This means that the cosine of the angle (θ) for each light source is the effected factor added to the intensity of the pixel in order to find the final brightness of it (Lambertian law).

Fusion: It is a process of meaningful merging of various imaging sources in order to produce more informative image (when fusion process between different scenes) or enhance image that take value which estimated by the powered of pixels values from each image (when fusion process between different images for the same scene). Image fusion process can be applied at many levels, generally, there are four levels of fusion.

- 1) Pixel-Level Fusion: The pixel-level fusion for images provides fine output information by applying the fusion operation among all pixels of the source images [4]. The goal is to combine and keep in a single output image all the important visual information found in the original images, pixel-level fusion. It can be classified into three types:
 - Linear methods, such as average and principal component analysis (PCA), are based on a weighted combination of positions from the source images [3].
 - Nonlinear methods: select minimum or maximum among the source images.
 - Multi-resolution Methods: Multi-resolution methods divided in two subgroups: pyramid and wavelet transform methods. So, every source image is decomposed into a pyramid of edge information at different resolutions. Discrete wavelet transform methods are similar to pyramid methods but give better results than the pyramid methods [4].
- 2) Feature Level Fusion: The fusion of important information on the level of features extracted from the image series initially. These features may be generated from single images (local texture features) or by a simultaneous evaluation of the entire images [5].
- 3) Region-Based Image Fusion: The basic idea is to perform a segmentation process for all original images and then use the segmentation results to guide the fusion process [3]. The region-based fusion can obtain the best results by considering the nature of points in each segment. Region-based methods design different rules for various regions fusion [5].
- 4) Decision-Level Fusion: Fusion at decision level combines the decisions of independent sensor detection or classification by Boolean (AND, OR) processes or by a selected suitable score. In the decision-level fusion, each sensor generates independent processing task, and then the outputs from each sensor are combined via a fusion operation [1].

Haar wavelet transform of multiple images for the same object with various light sources position in each image divided each image into four regions (LL, LH, HL, HH) by applying the following filters in horizontal and vertical directions.

$$L = \begin{bmatrix} 1 & 1 \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \quad H = \begin{bmatrix} 1 & -1 \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

II. LITERATURE REVIEW

Mohamed Anouar Borgi et al. in [7], presented a novel method for three dimensions of face recognition that merges dissimilar features by using guide method based on belief functions. The first feature model is generated via wavelet algorithm. In the second feature models, each facial surface is enhanced by a collection of facial curves based on geodesic distance. Finally, the fusion operation adopts a refined model of belief function.

In [11], proposed a novel, fast and robust method for obtaining 3D models with high-quality appearance using RGB-D sensors. This method uses a direct keyframe based

SLAM frontend to consistently estimate the camera motion during the scan. The aligned images are fused into a volumetric truncated signed distance function representation, from which a mesh is extracted. This method provides superior quality in appearance compared to the other state-of-the-art approaches.

In [12], proposed an algorithm, which allows creating simplified 3D models with high quality RGB textures. This is achieved by (i) creating model textures using images from an HD RGB camera calibrated with Kinect depth camera, (ii) using a modified scheme to update model textures in an asymmetrical color volume that contains a higher number of voxels than that of the geometry volume, (iii) simplifying dense polygon mesh model using quadric-based mesh decimation algorithm, and (iv) creating and mapping 2D textures to every polygon in the output 3D model. This work is implemented in real-time by parallel processing.

III. RESEARCH METHODOLOGY

The proposed system can be explained by the following steps, as illustrated in Figure 1.

A. Input Mesh

One of the most well-known methods in mesh constructing is triangulation-based technique that is quite simple and produced real accepted results. A mesh can be defined as a tuple (V, K) where $V = \{v_i \in R^3 | i = 1, \dots, N_v\}$ is the set of the vertices, and K contains the adjacency information or, in other words, how the vertices are connected to form edges and faces of the mesh of the final representation of the object [8].

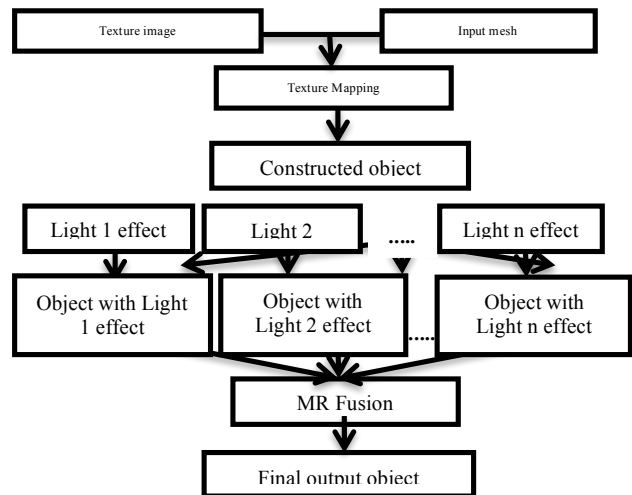


Figure 1: Block diagram of the proposed system

B. Texture mapping

In this stage of the proposed system Barycentric Coordinate Interpolation from the texture image coordinates to object coordinates to find the corresponding pixel for each point of the object. This stage consists of two main steps to perform Barycentric coordinates, which are

- 1) Test if the point is inside the triangle.
- 2) Find which pixel of the texture represents this point of the triangle by applying liner interpolation for the color and light or lights.

If points P1, P2, and P3 are triangle points, Then, any point P in the plane can be described by

$$p = a \times p_1 + b \times p_2 + c \times p_3 \quad (1)$$

The three Barycentric coordinates (a, b, c) sum to 1 and if they are all nonnegative, then the test of point (p) is positive and p is inside the triangle.

P is below from the bottom of edge P2P3 in the Figure 2. Then, the triangle PP2P3 has a negative value and the vertices given in the order P, P2, P3 are traced in a clockwise order rather than in the counterclockwise order, when P is above the bottom edge.

To find the Barycentric coordinate for each point in triangle, it is important initially to find the normal of triangle in that point. Each point in the triangle divides triangle into three sub triangles, as illustrated in Figure 2, then to calculate the normal vector of triangle, there is a need to find two vectors on it and calculate their cross product. The two suitable vectors are the distance between two vertices of the triangle. If we have the triangle in Figure 2,

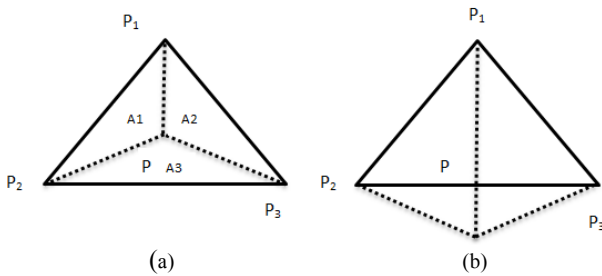


Figure 2: Inside triangle test (a) inside point(p) and (b) outside point(p)

Two vectors are $U_1 = p_1 - p_2$ and $U_2 = p_1 - p_3$, where p_1, p_2, p_3 are the triangle vertices, and the cross product is [10]:

$$\begin{aligned} N &= U_1 \times U_2 = \\ &U_{1y} \cdot U_{2z} - U_{1z} \cdot U_{2y}, \\ &U_{1z} \cdot U_{2x} - U_{1x} \cdot U_{2z}, \\ &U_{1x} \cdot U_{2y} - U_{1y} \cdot U_{2x} \end{aligned} \quad (2)$$

Barycentric coordinates of any point in triangle can be defined as a ratio of triangle areas. As illustrated in Figure 2, if A is the area of triangle $\Delta (p_1, p_2, p_3)$:

$$\begin{aligned} a &= \frac{\text{area of } \Delta p p_2 p_3}{A}, \\ b &= \frac{\text{area of } \Delta p p_3 p_1}{A}, \\ c &= \frac{\text{area of } \Delta p p_1 p_2}{A} \end{aligned} \quad (3)$$

$$\begin{aligned} p_x &= a \times p_{1x} + b \times p_{2x} + c \times p_{3x}, \\ p_y &= a \times p_{1y} + b \times p_{2y} + c \times p_{3y} \end{aligned} \quad (4)$$

Then A defined as [6] [10]:

$$A = |N| = \|(p_1 - p_2) \times (p_1 - p_3)\| \quad (5)$$

$$a = \frac{N \cdot N_1}{|N|^2} \quad (6)$$

$$\begin{aligned} b &= \frac{N \cdot N_2}{|N|^2} \\ c &= \frac{N \cdot N_3}{|N|^2} \end{aligned}$$

The results of applying barycentric coordinates are explained in Figure 3.

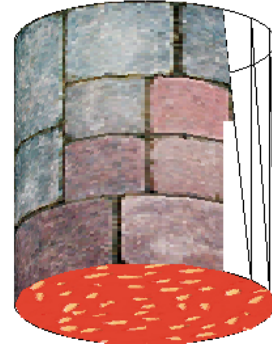


Figure 3: Texture mapping with Barycentric coordinates

C. Lighting

Light in three dimensions graphics makes a scene more realism. There are various levels of realism which can be added to objects for a given scene. Wireframe images (triangles mesh) is the first step, where drawing the triangles, can give an initial sense of the scene, but coloring the triangles at least with single color can begin to flesh it out. Simple lighting and shadows are enough to give a three-dimensional sense and shape to a scene, as illustrated in Figure 4.

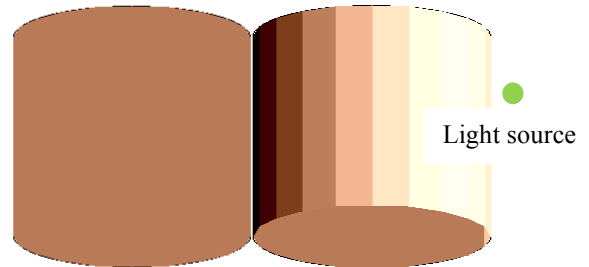


Figure 4: Light effect on object realism

If the incoming light from the source is perpendicular to the surface at a particular point, that point is fully illuminated. As the angle of illumination (θ) between the surface normal (N) and light direction moves away from the surface normal, the light effect at that point drops off, thus the $(\cos \theta)$ is the effected values that added to the intensity of the pixel to add the illumination to it.

$$\text{Cos}\theta = N \cdot L \quad (7)$$

where N is the normal of the surface at a specific point of the surface. L is the distance vector from the light source to the surface. The result of applying light effect can be enhanced to avoid stopping region and edges between different light intensity [2] and make the object more realism as illustrated in Figure 5.

D. MR fusion

Applying fusion methods between the coefficients of

wavelet transform in one image with corresponding coefficients of the other images and applied max, min and/or different ratio methods to obtain more than one result and then select the suitable one is illustrated in Figure 6.

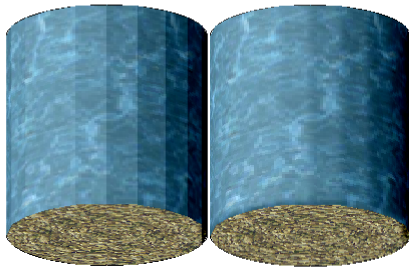


Figure 5: fining the effect of light

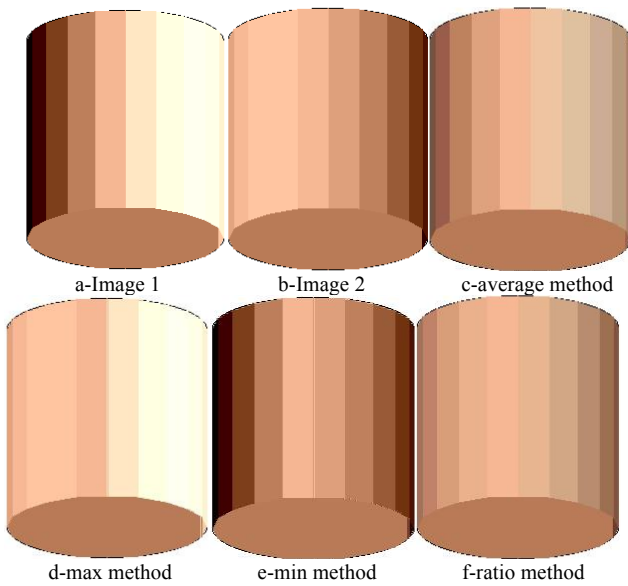


Figure 6: Fusion of two sources of light by different methods

IV. ANALYSIS

Texture mapping gives input mesh some three dimensions appearance by mapping an image with some textures that contain multiple colors. Based on MR fusion method, there are many results by taking different types of linear or non-linear fusion methods. All of these results have the degree of realism with various accepted results.

V. RESULTS AND DISCUSSIONS

When we applied the proposed system on selected examples, the following results were calculated, where represents Light source.

$$Psnr = 10 \log_{10} \frac{255^2}{\sum_{i=1}^{s1} \sum_{j=1}^{s2} [z(i,j) - o(i,j)]^2} \quad (8)$$

Where:

- Z : output image.
- O : original image.
- S1 : images width.
- S2: images height.

Example 1:

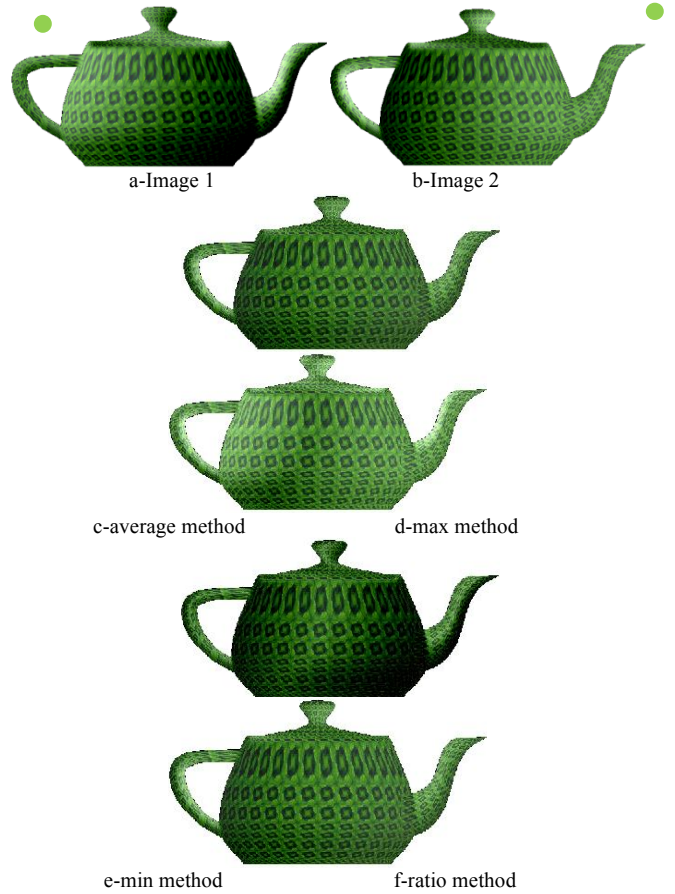


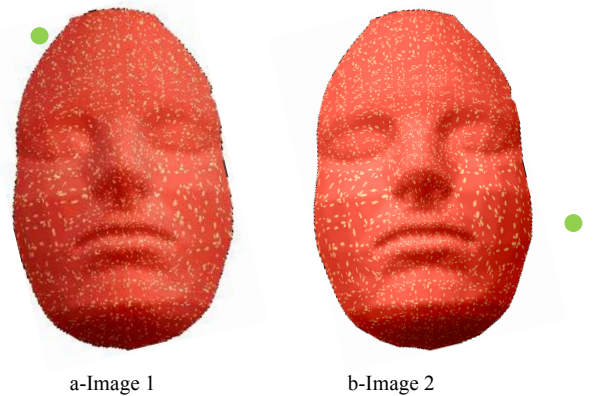
Figure 7: Example 1 results

When *Psnr* is calculated among original and fused images, the results can be organized as shown in Table 1.

Table 1
Psnr Results of Example 1

Images	Average Fusion	Max Fusion	Min Fusion	Ratio Fusion
Image 1	32.8	46.12	31.9	32.53
Image 2	31.08	43.14	30.54	31.69
Average	31.94	44.63	31.22	32.11

Example 2:



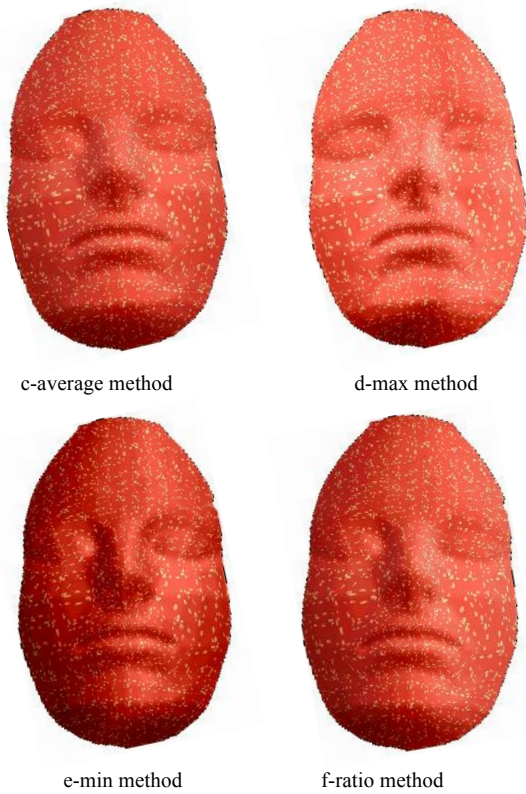


Figure 8: Example 2 results

The values of Psnr are in Table 2.

Table 2
Psnr Results of Example 2

Images	Average Fusion	Max Fusion	Min Fusion	Ratio Fusion
Image 1	28.98	44.57	28.62	28.8
Image 2	31.51	48.39	30.62	32.49
Average	30.24	46.48	29.66	30.64

Example 3:

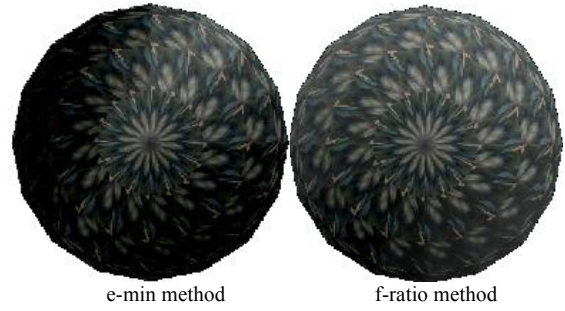
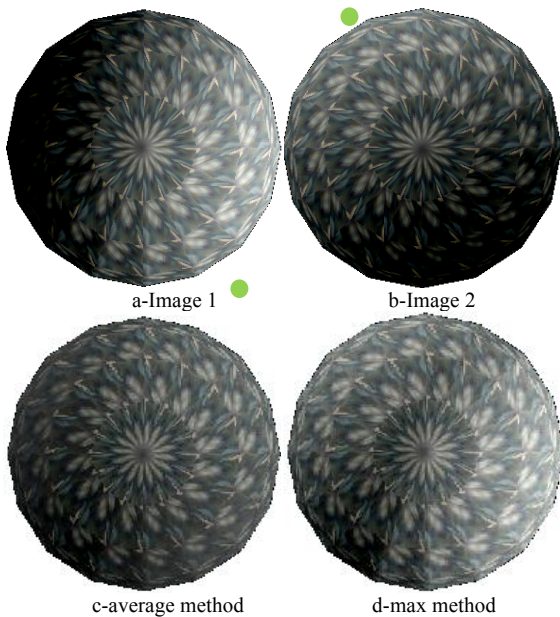


Figure 9: Example 3 results

The values of Psnr are shown in Table 3.

Table 3
Psnr Results of Example 3

Images	Average Fusion	Max Fusion	Min Fusion	Ratio Fusion
Image 1	29.15	46.23	28.66	28.91
Image 2	31.07	45.97	30.56	31.66
Average	30.11	46.1	29.61	30.28

VI. CONCLUSION

After applying the proposed system, we can discover that the fusion operation of multiple light sources gives acceptable degree of realism and provides accepted 3d objects. Maximum method fusion gives more white light effect and more acceptable results because the three examples demonstrated by this method have the highest psnr. On the other hand, the average and ratio methods fusion give accepted results with accepted realism even with large number of light sources. As shown in psnr results, ratio method is slightly better than the average method. However, the min method fusion gives fine results with beautiful accepted shadow, although it does not reflect the real state of the lights, resulting in the worst result. In ratio method fusion, the ratio can be selected to reflect the intensity of each light source as well as its distance from the object.

VII. REFERENCES

- [1] I. D Hall and I. James, " Handbook of Multisensor Data Fusion ", 2001 by crc press LLC, ch. 4.
- [2] N. Bannai , R. B. Fisher and A. Agathos, "*Multiple color texture map fusion for 3d models*", 2006 , Elsevier, United Kingdom, School of Informatics, University of Edinburgh.
- [3] T. Stathaki, "*Image fusion: Algorithms and applications*", First edition 2008, Academic Press is an imprint of Elsevier, USA, ch. 14 and ch. 4.
- [4] O. Ukimura, "*Image fusion*", 2011, Intechweb.org, Published by InTech Janeza Trdine 9, 51000 Rijeka, Croatia, Ch. 2 .
- [5] S. Ahmed and K. M. Iftekharuddin, "Efficacy of texture, shape, and intensity feature fusion for posterior-fossa tumor segmentation in mri", *IEEE transactions on information technology IN BIOMEDICINE*, vol. 15, no. 2, March, 2011.
- [6] E. A. A. Bayee, "*Develop a 3D Visualization GIS Tool Using Texture Mapping*", Thesis in Computer Science, Babylon University, Iraq, 2012, ch.2.
- [7] M. A. Borgi and M. E. Arbi, and C. B. Amar, "Wavelet network and geometric features fusion using belief functions for 3d face recognition", *CAIP 2013, Part II, LNCS 8048*, pp. 307–314, Springer-Verlag Berlin Heidelberg 2013.
- [8] I. Hadi and S. T. Hasson, "Graph Construction Based on Data base of Movie Objects", *Oriental journal of computer science & technology*, India , ISSN: 0974-6471 June 2013, Vol. 6, No. (2): Pgs.61-65.

- [9] J. F. Hughes, "*Computer graphics principles and practice*", third edition, 2014, Addison-Wesley, united states of America
- [10] J. Vince, "*Mathematics for computer graphics*", Fourth edition, 2014, Springer-Verlag, London, ch.11.
- [11] R. Maier, "*Super-Resolution Keyframe Fusion for 3D Modeling with High-Quality Textures*", Computer Vision Group, Technische Universit at M unchen, Germany, 2014.
- [12] Song Liu, et. al., " Creating Simplified 3D Models with High Quality Textures", University of Wollongong, Wollongong, NSW, Australia, , Date of Conference: 23-25 Nov. 2015, *IEEE*.
- [13] F. Gnovelli, M. Corsini, S. Pattanaik and M. D. Benedetto, "*Introduction to computer graphics a practical learning approach*", 2015 by Taylor & Francis group, ch.3 and ch6.
- [14] S. J. Janke," *Mathematical structures for computer graphics*", 2015 by John Wiley & Sons, ch.6 and ch.9.