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A Novel Texture Mapping Method in Constructing 3-D Object Depending on Triangle Features

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Abstract: In the proposed system a new method will be used in mapping texture from texture image to a specific triangle mesh by dividing the mesh of specific object into three parts of meaningful regions, each part of them used specific method to map texture image or fused texture image into object mesh where the first group used multiple texture images with region fusion method that depend on some of GLCM features in selecting specific region from one of the texture images and then depending on the area of this region this region will be mapped into triangles with suitable area according to limited condition such as equality between these areas. While the second group of regions used pixel fusion method to produce fused image that is similar to all input image and merge them in some specific fashion but specific parts from this image will be used as a texture triangle to be mapped into mesh triangle also depending on suitable features such as direction of the triangle and finally the third group of regions used suitable texture image to be mapped completely by dividing this image into same triangles that used in the mesh of the region. The proposed system produce flexibility and reliability in the final object by taking light effect that make the result more beauty.

Key words: Texture mapping, region fusion, GLCM, light sources, contrast, watershed, wavelet

INTRODUCTION

Fusion is the process of merging many input images into a single output image either for the purpose of making output image with best quality or more informative than any of the original images by applying some merging operations in specific level (Rick and Zheng *et al*., 2006) such as pixel level fusion for the purpose of merging and saving in a single image all the important information from various original input images, pixel-level fusion mainly classified into many types such as linear methods by taking the average among all fused pixels, nonlinear methods by selecting minimum or maximum pixels value and multi- resolution methods such as wavelet transform methods, feature level fusion by extracting features from the fused images and then use these features as a guide for fusion process (Alparone *et al*., 2015), region based image fusion: considering the nature of each segment rather than each pixel alone (Raol, 2015) and decision level fusion: like classification, results from different sources are merged to generate decisions that are compatible and this process done (Alparone *et al*., 2015) by combining the decisions of independent and unrelated sensor by Boolean (and or) operations or by selecting a suitable score depending on the importance of each part.

Region fusion methods need image segmentation as an important and intermediate operation in order to divide image into homogenous regions according to some specific features, one of the most important segmentation method with perfect results is watershed algorithm which has many copies but the essential and vital idea performed by simulating a watershed process on topographic image that constructed by taking the value of each pixel as an elevation level of this point and construct dams lines, progressively between different regions to prevent water from different regions to be merged and these dams at the end represent the segmentation lines between objects in the image (Baker, 2014).

There are many statistical methods for calculating texture features in order to select suitable region that satisfy some criteria, one the most important and common method is Gray Level Co-occurrence Matrix (GLCM), the GLCM work initially by constructing a matrix with number of rows and columns are equal to the number of gray levels in the image with values of the matrix represent the differences between pixel gray level and its neighboring pixels at a specific displacement distance and at a selected angle (Nidhal *et al*., 2015).

The process of generating 3D object models requires a huge amount of time and effort but some modeling tools make this operation fast and easy, modeling operation ways such as 3D polygon mesh by dividing flat surface into polygonal units like triangles (Gortler, 2012) and Constructive Solid Geometry (CSG) by combining some

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basic primitives in a desired fashion with specific operations like union, difference and intersection (Hughes and Foley, 2014).

Texture Mapping (TM) operation can be defined as an operation of constructing a 3D model by mapping specific scene from a 2D texture image and applying specific selected interpolation processes (Mukai, 2012) that calculated for each object point, the corresponding pixel in the texture image that must be mapped to it (Hughes *et al*., 2014) there are some supportive techniques used to make 3D object look more realism, by adding suitable amounts of properties like color, light and shadow. TM methods can be classified mainly into nearest neighbor TM coping the value of the closest texel, linear TM using linear interpolation as an index compared to the points of the mesh, bilinear TM applying two successive unrelated linear interpolation operations and projective TM; This method is useful in mapping light and shadow operations.

Lighting is a complex operation required complex calculations in a scene because there are many processes related to this operation such as reflections, refractions and diffractions taking place everywhere in the scene as well as many types of lights such as constant ambient light, diffuse light that assumed equally in all directions and specular light that reflected to the viewer (Zhang *et al*., 2017).

There are many accepted models of light and shading techniques such as lambertian law, phong model, gouraud model, cook-torrance model, oren-nayar model and minnaert model where each one of these models try to satisfy an acceptable tradeoff between two important factors reality of the objects and complexity of the calculation by rejecting or accepting some parts of light components in scientific fashion (Ganovelli *et al*., 2014).

Literature review: Zhang *et al*. (2014) proposed novel region fusion by using watershed segmentation method depending on desired and selected threshold. This proposed method combine regions with nearest average color and check those that satisfy the similarity between regions average color depending on specific threshold. the proposed method divided the image into large areas and calculate edge information speedy.

Li and Yang (2008) proposed a new region based multi-focus image fusion method by applying following steps: firstly, input images are fused with simple average pixel fusion method then the intermediate output image is segmented using the normalized cut algorithm and the two multi-focus images are divided in the same fashion according to the results of the segmentation of intermediate fused image. Finally, the corresponding segmented regions of the multi-focus images are fused according to their spatial frequencies, raw and column frequency to select good region from one of the multi-focus images.

Jin *et al*. (2014) present a texture mapping method controlled by importance map to save the shape of the salient content. they formulate it as an importance-value-weighted parameterization. The mapping distortions are measured by LSCM and energy metrics which is useful in decreasing the appearance of retract as well as shape keeping and the weights are calculated by using transformation from area integral into line integral they employ the Levenberg-Marquardt transform and continuously update the weights and the coordinates since there are mutual dependences between them.

MATERIALS AND METHODS

Proposed system: The proposed system is shown in Fig. 1 consist of number of parts and we describe each part as follows.

Part 1; Mesh preprocessing: The input mesh of triangles consist of control points and groups of three lines with nearest points that construct the essential shape of the object each point described by three coordinates width, height and depth (x-z) and each triangle described by three control points and three lines, the mesh divided into different meaningful regions with specific texture that differ from other regions of the mesh as shown in Fig. 2 and these regions classified into three types of triangles (parts), the first type of triangles used region fusion method to construct texture image that will be used in mapping process, the second parts of triangles used MR fusion method in constructing final texture image and the third type of triangles used pixel fusion and divided texture image in same way as part of mesh to map complete texture image.

Part 2; Region fusion: This part of the proposed system takes specific type of triangles from the mesh and apply number of operations start with entering texture images. Texture image is a raster image with texels (texture element) any position in a texture image is assigned by texture coordinates (UV-coordinates). Operations in this part of the proposed system may be divided into number of operations that can be illustrated as follows.

Region fusion method: In this step of the proposed system many operations among texture images will be

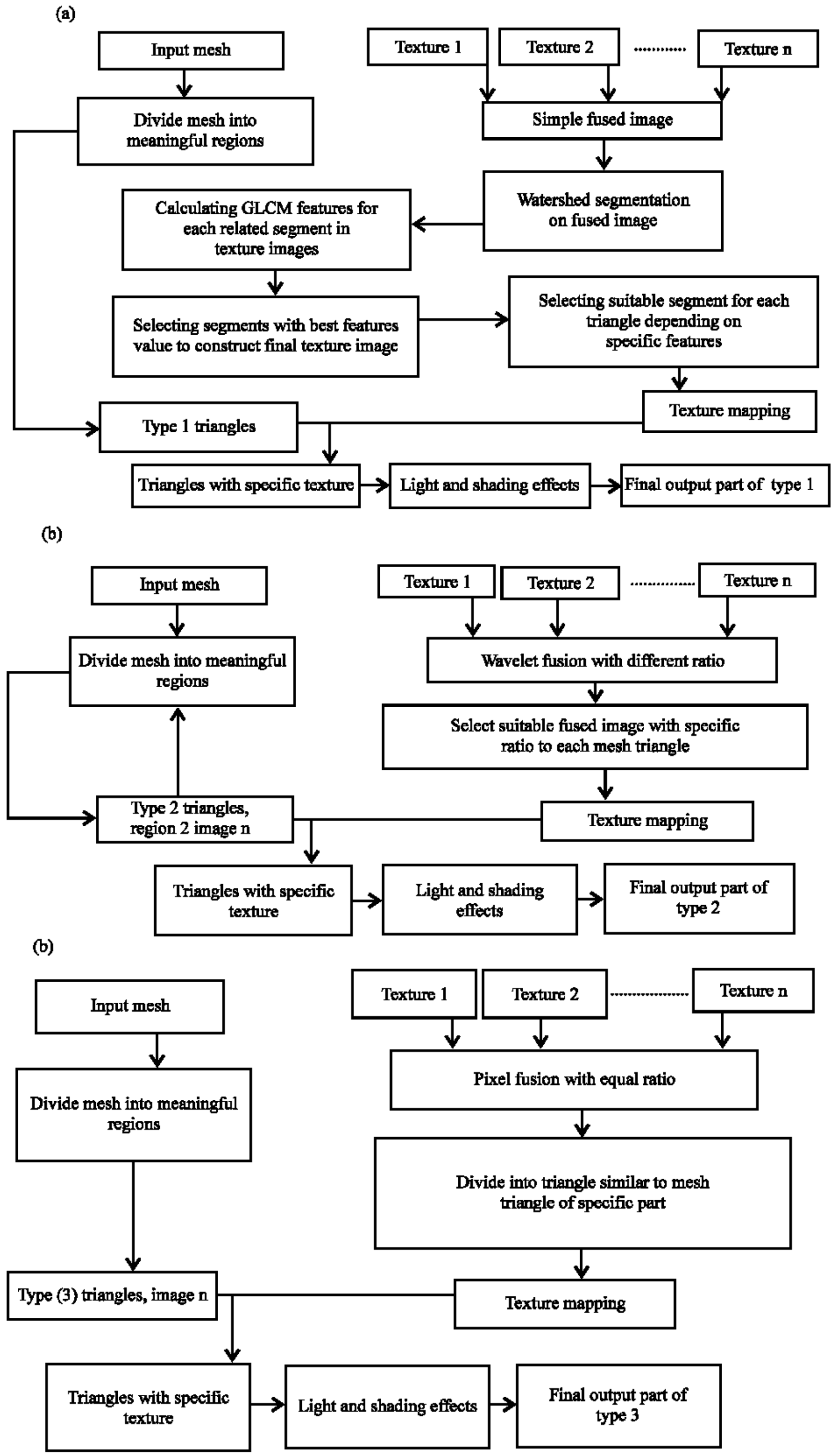

Fig. 1: Block diagram of the proposed system: a) Block diagram for type 1 triangles; b) Block diagram for type 2 triangles and c) Block diagram for type 3 triangles

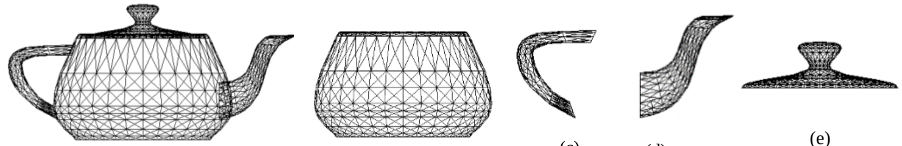

Fig. 2: Divide mesh into meaningful regions: a) Input mesh; b) Region 1; c) Region 2; d) Region 3 and e) Region 4

Fig. 3: Average fusion between texture images: a) Texture 1; b) Texture 2 and c) Intermediate texture

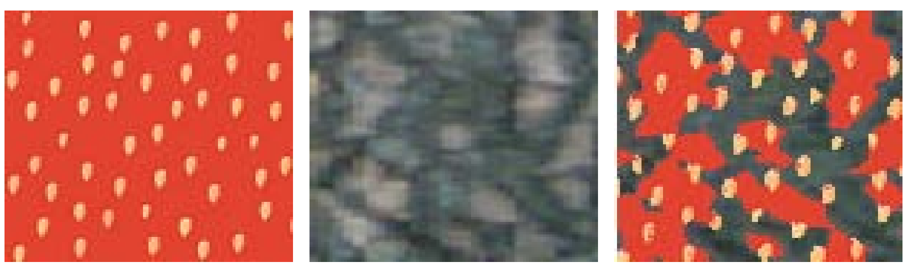

Fig. 4: Constructing of final texture image

applied and initially, a linear pixel fusion method with equal ratio will be applied among texture images to construct Intermediate Texture Image (ITI) that will be processed before mapping to object mesh as shown in Fig. 3.

Watershed segmentation: The watershed segmentation method consists of the following processes. Image enhancement and gray level reduction the Intermediate Texture Image (ITI) enhanced by applying mean filter between each pixel and its 8-neibouring pixels as shown in Fig. 4 in order to delete noise effect and enhance image to avoid the irregular effects in the final image:

$$P_{new} = \frac{1}{9} \times (p1+p2+p3+p4 +pold+p5+p6+p7+p8) \quad (1)$$

This step may be repeated several times as a first process to overcome the over segmentation problem that divided each segment into meaningless small segments that don't reflect real parts of object. The second process in this operation in order to avoid over segmentation problems in watershed segmentation is gray level reduction by suitable factor.

$$p_{new} = NGL \times \frac{pold}{OGL} \quad (2)$$

Where:

NGL = Desired number of gray levels in output image after reduction

OGL = Number of gray levels in input intermediate image before reduction

Neibouring pixels:

P1	P2	P3
P4	p	P5
P6	P7	P8

Edges detection by drawing initial arrows (edges) from any pixel to other pixels in its 8-neibouring pixels with great gray level value as illustrated in Fig. 3 then deleting all arrows entered and leaved a pixel if this pixel received more than two arrows from its 8-neiboring pixels, then the residual lines represent the final arrows or edges between objects as illustrated in Fig. 3.

Labeling all pixels in any isolated region with unique number that represent the region number that used to retrieve all pixels in a specific segment with stable number.

RESULTS AND DISCUSSION

Calculating GLCM features for each related segment in texture images: In this step of the proposed system the context will be selected and the gray level co-occurrence matrix will be constructed by adding one in any matrix cell for each pixel that satisfy the specific context and this process applied to each pixel in a specific region until constructing GLCM for each region in all input texture images. After constructing GLCM features such as contrast and entropy will be determined as follows:

$$\text{Contrast} = \sum_{x=0}^{1-1}\sum_{y=0}^{1-1}(x\text{-}y)^2 \times \text{GLCM}(x, y) \quad (3)$$

$$\text{Entropy} = \sum_{x=0}^{1-1}\sum_{y=0}^{1-1}\text{GLCM}(x\text{-}y) \times \log \text{GLCM}(x, y) \quad (4)$$

where, L is number of gray level in the segment. Then each region will be selected from input images with best values of these features to construct final texture image as shown in Fig. 4 and these regions will be mapped to triangles if triangle area is compatible with region area as well as the triangle in the texture image has fixed shape with different dimensions depending on the dimensions of the triangle.

Texture mapping: In this stage of the proposed system a linear interpolation method with barycentric coordinate will be applied to translate pixels from texture coordinates to object coordinates by finding the corresponding pixel for each point in the object.

$$p = u \times p_1 + v \times p_2 + w \times p_3 \quad (5)$$

$$u + v + w = 1 \quad (6)$$

(u, v and w) are barycentric coordinates and if they are all nonnegative, then point p is inside the triangle $(p_1p_2p_3)$,

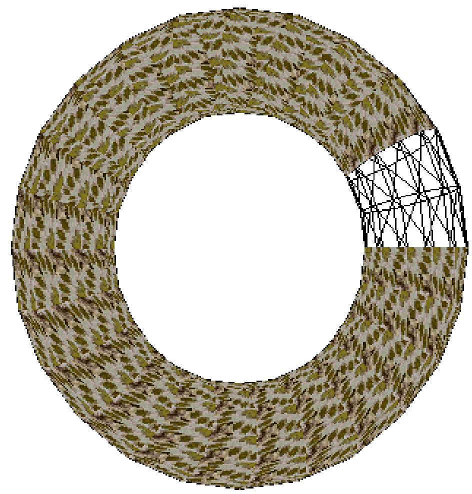

Fig. 5: Texture mapping with barycentric coordinates

then to calculating the normal of triangle, two vectors $U_1 = p_2\text{-}p_1$ and $U_2 = p_3\text{-}p_1$ and the normal is the cross product is:

$$N = U_1 \times U_2 = U_{1y}.U_{2y}, U_{12}.U_{2x}\text{-}U_{1x} \; U_{2z}, U_{1x}.U_{2y}\text{-}U_{1y}.U_{2x} \quad (7)$$

Barycentric coordinates of any point in triangle can be defined as a ratio of triangle areas:

$$u = \frac{\text{Area of } \Delta pp_2p_3}{A}, \quad v = \frac{\text{Area of } \Delta pp_3p_1}{A}, \quad w = \frac{\text{Area of } \Delta pp_1p_2}{A} \quad (8)$$

The TM process select specific region to be mapped to specific triangles depending on specific features from these two sides such as area, aspect ratio and the length of triangle in one coordinate. The results of applying texture mapping method explained in Fig. 5.

Part 3; MR fusion

Texture images input

MR image fusion: Each texture image divided into four regions (LL, LH, HL, HH) by applying low$[\frac{1}{\sqrt{2}} \frac{1}{\sqrt{2}}]$ and high$[\frac{1}{\sqrt{2}} \frac{1}{\sqrt{2}}]$ filters then linear fusion by using various ratio from all texture images will be applied to obtained fused wavelet coefficients which translate again into pixels values by applying inverse wavelet transform on the fused coefficients.

Texture mapping: This operation depending on the direction of mesh triangle in transmitting part of mesh with specific variance value of texture triangle and this operation depend on ration from each texture image.

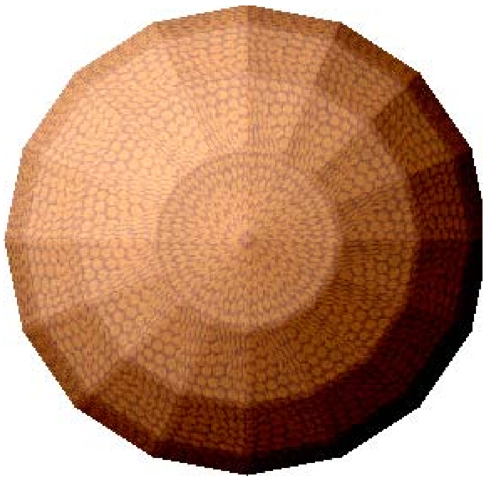

Fig. 6: Flat light effect on object realism

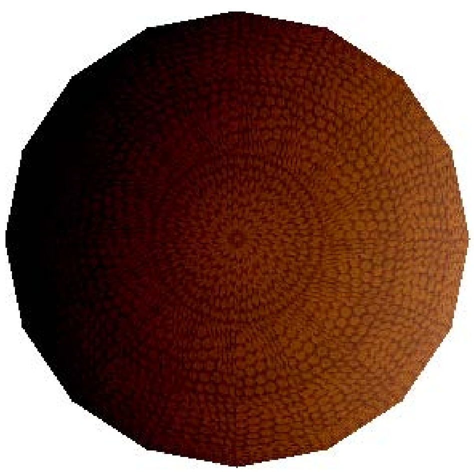

Fig. 7: Fining the effect of light

Part 4; Pixel fusion and mapping complete texture image:

- Texture images input
- Simple pixel fusion with equal ratio from each pixel in texture images
- Divided fused image in same way as triangle region
- Texture mapping of the whole scene

Part 5; lighting and shading: Lights in three dimensions graphics make scene look real, the proposed system used Lambertian law by calculating cosine of the angle (θ) between normal and light direction. Simple light and flat shadow are enough to add a three-dimensional effects to the object or scene as shown in Fig. 6.

The result of light effect can be enhanced by taking the average of light values of each triangles shared specific point to make the object more realism as shown in Fig. 7 lighting and shading operations applied on all triangle types in part 2-4. The proposed system applied on specific examples, the following results will be calculated where represent light source (Fig. 8-10).

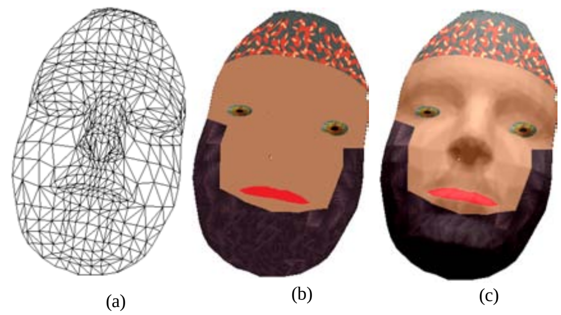

Fig. 8: Example 1 results: a) Triangle mesh; b) Image after texture mapping and c) Image with light effect

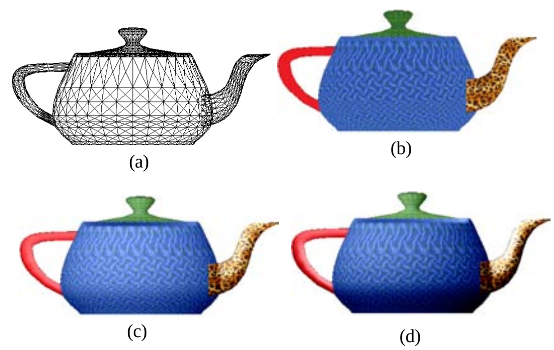

Fig. 9: Example 2 results 1: a) Triangle mesh; b) Image after texture mapping; c) Image with light effect 1 and d) Image with light effect 2

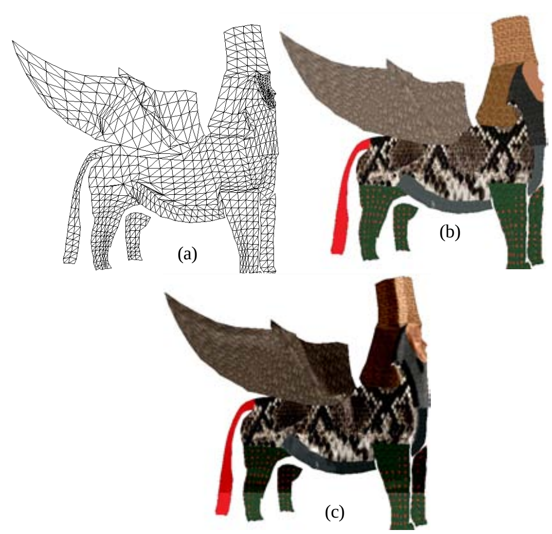

Fig. 10: Example 3 results: a) Triangle mesh; b) Image after texture mapping and c) Image with light effect 1

CONCLUSION

The proposed system provide flexibility in constructing proposed object with different texture regions and the three methods of mapping triangles provide different results some of them are not predicted where the mapping of total texture as a whole provide predictable results as well as the result of wavelet fusion is predicted in the mapped triangle but region fusion provide unpredicted texture that can be used in places that not related with fixed texture to provide beautiful effect on the whole result.

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