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A Novel Fusion Method in Texture Mapping Environment

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Abstract: A novel method will be proposed not only in determining the value of pixels in final fused image but also in finding the suitable triangle in three dimension mesh of triangles for object and then mapping the texture triangle into correct selected mesh triangle until building fused mapped object and then taking the effect of light sources. The novel fused method in region level of fusion methods that initially produce intermediate fused image by applying variance fusion method among all input texture images, then applying segmentation process on the intermediate fused image to separate it into non overlap regions, then selecting one of these regions to be mapped to suitable triangle depending on a value of suitable feature for these regions and this process repeated until constructing the final fused mapped image. The proposed method extended the effect of fusion methods to select good places for mapping pixels as well as to find pixels values that reflect the effect of input light sources.

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

INTRODUCTION

Solid modeling methods provides a general and clear definition of a scene, Modeling is an operation of building a desired 3D objects either from real objects or an imaginary ideas. Modeling process can be applied in many ways such as 3D polygon mesh: this way is common strategy that divided a flat surface into parts of polygons (Gortler, 2012) like triangles, quadrilaterals, etc. and Constructive Solid Geometry (CSG) which assumes that real objects can be constructed by merging basic primitive shapes by applying specific operations between them. A set of solid primitives are combined by different mathematical or logical operators (Chen and Wegman, 2006).

Texture Mapping (TM) can be explained as a translation from a texture image to the mesh of a three dimensions object, it converts texture skins to a polygon mesh via. assigning texture point to each vertex (Avots *et al*., 2016) each point on the surface is related with a specific pixel in the texture image (Yao *et al*., 2013) this technique add some surface properties to the object, like color, bumps, light and shadow. Mapped image is a colored image and its pixels called texture elements (texels) a position in texture image is specified by UV-coordinates (Ganovelli *et al*., 2014). TM techniques can be classified into the following algorithms:

- Nearest neighbor TM: by selects the color of nearest texel
- Linear TM: finds texel for each vertex and by using linear interpolation calculating interior points of each triangle
- Bilinear TM: performs linear interpolation in one direction, then in the other one
- Projective (perspective) TM: t allows a textured image to be projected onto a specific surface

Special mapping methods, this methods are:

Bump mapping: It is simulating bumps as well as wrinkles on a specific, surface by changing the value of the normal of object surface, during light calculations.

Displacement mapping: It involves changing of the position of the pixels in the surface and mostly occurs along the normal direction.

Barycentric coordinate interpolation: It is an important techniques for dealing with triangles that initially check if the desired position is inside the triangle then linear interpolation depending on the ratio of areas related to this position with each vertex (Janke, 2014).

Lighting is a complex effect in a scene because there are many reflections, refractions, diffractions and absorptions taking place everywhere in objects, there are typically three essential parts of lighting in many lights models. Ambient light considered constant, diffuse light For diffuse reflection, assumed equally in all directions and specular light when the light, source is actually reflected toward the viewer and not just reflected in all directions equally (Hughes and Foley, 2014).

There are many models for light such as Lambertian law where the illumination of the point depend on the angle between the light direction and the normal of the

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triangle, so, cosine of the angle (θ) is the effected factor that change the value of the pixel to produce the final color of this pixel (Tan and Cheng, 2016).

Fusion: Image fusion is the integration process of various related image data or details and multi-view information acquired in several domains into a single, output image with the best quality or with more information (Ukimura, 2011).

Pixel-level fusion: Used to increase information related with each pixel in an image constructed through a merging process of some images (Kumar and Kumar, 2015). The goal is to merge and save in one image all the important information from the essential images, pixel-level fusion classified into many ways: Linear methods like average, nonlinear methods by selecting minimum or maximum among all input images and multi-resolution methods such as pyramid and wavelet transform methods (Stathaki, 2008).

Feature level fusion: Performed among sets of features which are extracted from input images (Stathaki, 2008).

Region-based image fusion: Select suitable region from one of the input images depending on suitable features of the image (Li and Yang, 2008). These methods obtained good results by taking the nature of points in each segment into account (Stathaki, 2008).

Decision-level fusion: When results determined from more than one image are merged, to generate decisions that are accepted in decision level (Stathaki, 2008), so, decision level combines the decisions of different independent sensor by Boolean operations or by selecting suitable score for each sensor.

Image segmentation: It is the technique that used in dividing images according to some characteristics into suitable, non-overlap and uniform regions. No one single algorithm is perfect in all applications.

The watershed algorithm is morphological method of image segmentation, it is work by simulating a watershed process where the color value of pixels in image represent an elevation level of this point in topographic image and then building dams lines, regions are slowly flooded by raising water at a fixed rate, when the water from two regions is about to merge, a dam will be constructed. The flooding process stopped when only the dams are visible and these represent the segmentation lines (Baker, 2014).

Gray Level Co-occurrence Matrix (GLCM): It is an algorithm for determining texture features in statistical way that used in a number of applications essentially in object detection. GLCM is a matrix with dimensions equal to the number of gray levels in the image, the matrix elements contain values for changes between row and column gray levels at a specific context of displacement distance and angle (Nidhal.*et al*., 2015).

Literature review: Li and Yang (2008) proposed new region based image fusion algorithm. The fusion operation has the following steps: images fusion then the intermediate output image is divided into non-overlap regions then the two source images are segmented similar to the result of the intermediate image, finally, the segmented regions of the input images are fused depending on row and column frequencies. Experimental results reflect good results than the pixel-based methods. Hanusch (2008) applied a new TM approach which develops the known approaches of TM to three dimension objects, new algorithm is appropriate to perform high quality outputs by avoiding problems of previous techniques. Many image texture mapping operations enhanced, to save the fine texture information in the surface of the object and regularize shiny levels of the images in dataset.

Liu *et al*. (2015) presents an enhancement to the kinect fusion algorithm which allows constructing high quality textures 3D Models by creating model textures, using an enhanced approach to renewal textures in an asymmetrical color volume that contains high number of voxels, simplifying mesh of large number of polygons using quadric mesh and creating and mapping image textures to every polygon in the final three dimensions object.

MATERIALS AND METHODS

The proposed system: The proposed system consist of many steps as illustrated in Fig. 1.

Texture images: Texture image is a colored image with texels that detected by texture coordinates (UV-coordinates)

Simple pixel level fusion method: In this step of the proposed system variance fusion methods will be applied initially by selecting maximum(or minimum) gray level value from input images and then taking values from input images that make variance of each pixels with its neighboring pixel less until the last pixel in image to construct intermediate fused image (IF image) that will be enhanced before mapping to object mesh as illustrated in Fig. 2.

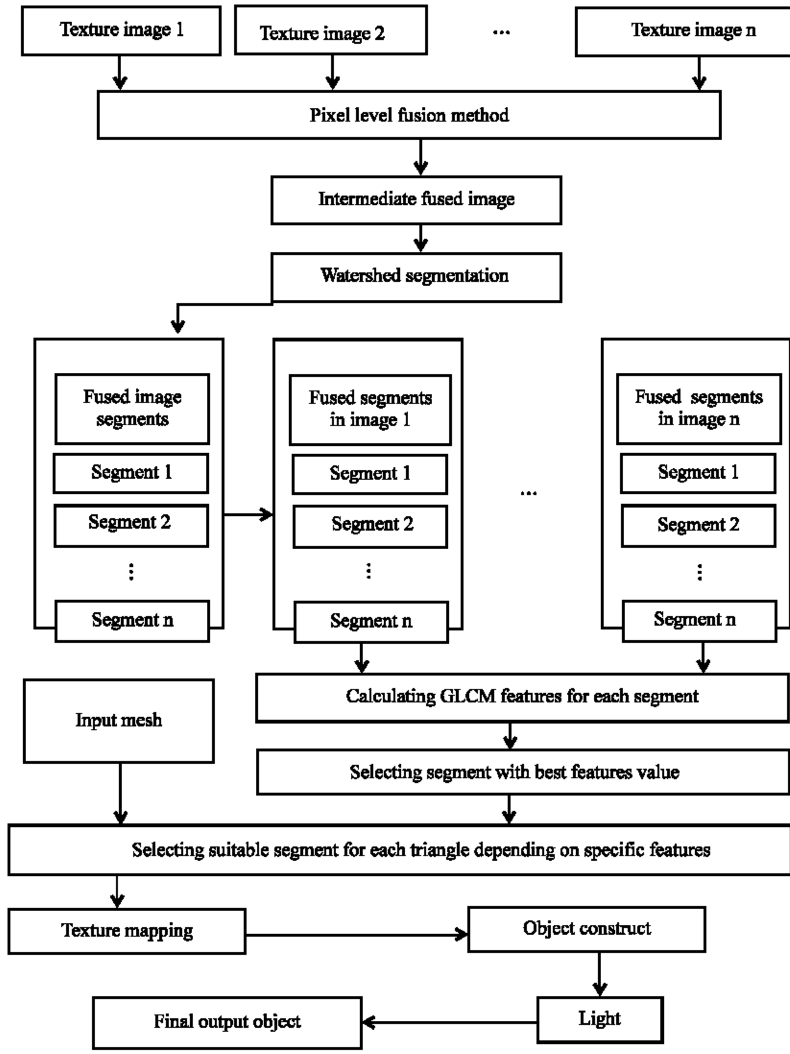

Fig. 1: Block diagram of the proposed system

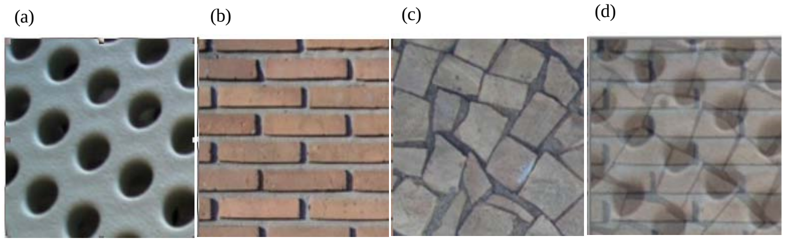

Fig. 2: Simple pixel level fusion between texture images: a) Texture image 1; b) Texture image 2; c) Texture image 3 and d) IF image

Watershed segmentation: The watershed segmentation consist of many processes; Image enhancement: the intermediate fused image enhanced by mean filter between pixel and its 8-neibouring of gray level image in order to delete noise effect and enhance image to cancel the unwanted appearance as illustrated in Fig. 3:

$$P(x,y)new = 1/9\times(p(x-1,y-1)+p(x-1,y)+ p(x-1,y+1)+p(x,y-1)+p(x,y)+p(x,y+1)+p(x+1,y) \quad (1)$$

This step may be repeated several times to overcome the over segmentation problem that divided each segment into meaningless small segments.

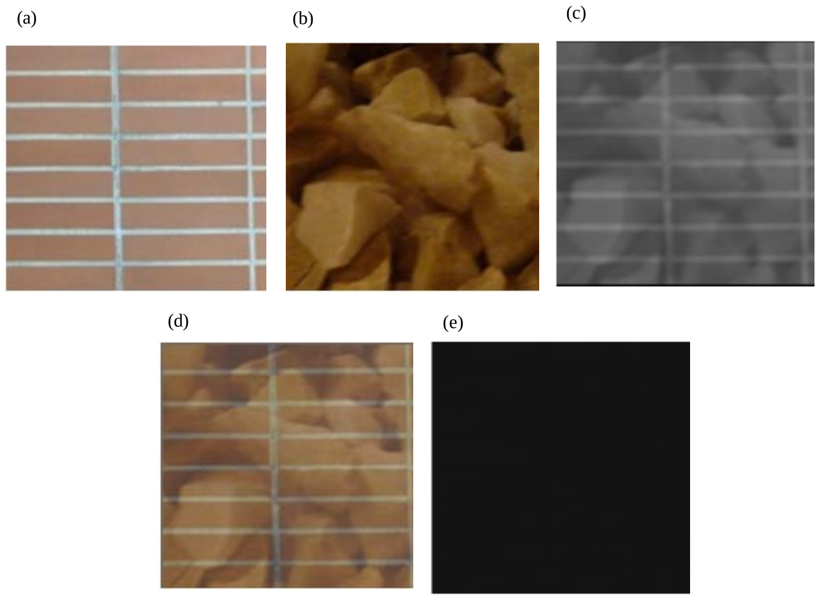

Fig. 3: Color reduction process for the fused image: a) Texture image 1; b) Texture image 2; c) IF image; d) Mean filter and e) Color reduction

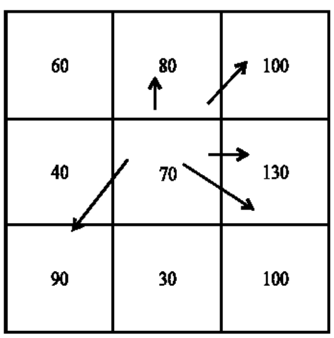

Fig. 4: Initial arrows

The second process applied to enhance image and avoid over segmentation is gray level reduction by using suitable equation for each gray levels as illustrated in Fig. 3:

$$p_{new} = 20 \times \frac{p_{old}}{255} \quad (2)$$

Edges detection: this step contains two important steps first one draw initial arrows from specific pixel to any pixel of its eight neighboring with great gray level value as illustrated in Fig. 4.

Then razing all arrows entered or leaved specific pixel if this pixel received more than two arrows from its 8 neighboring pixels to construct final arrows that represent edges between objects in the gray level version of the enhanced intermediate fused image as illustrated in Fig. 5.

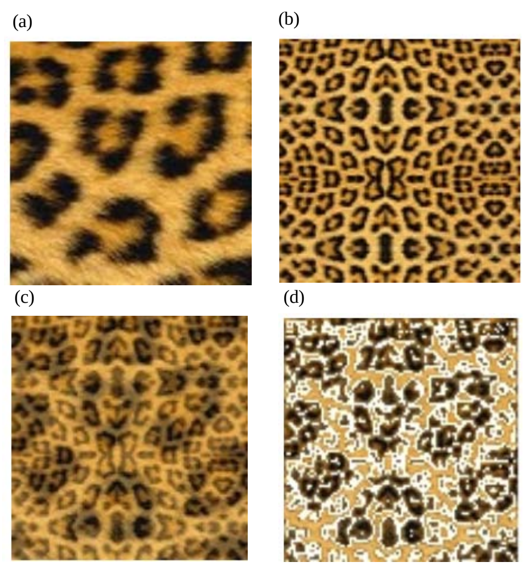

Fig. 5: Watershed dams: a) Image 1; b) Image 2; c) IF image and d) Edges detect

Labeling pixels in the isolated regions with a unique number that represent segment number of this region as well as the region number that used in retrieving pixels in a wanted segment with stable number.

Calculating GLCM features for each segment: In this step of the proposed system the GLCM matrix will be constructed by adding one in the position of the output matrix for each pixel that satisfy the relation of the selected context and this process will be checked for each

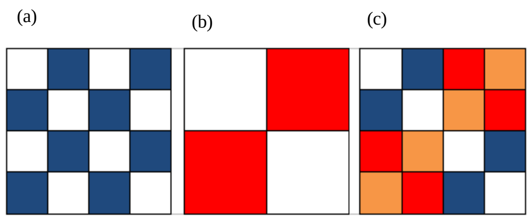

Fig. 6: Related segments among inputs and fused images: a) Image 1 segmentation; b) Image 2 segmentation and c) IF image segmentation

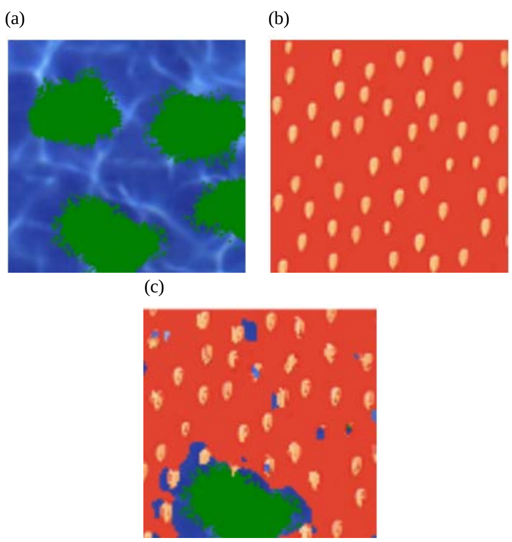

Fig. 7: Final fused texture image: a) Input image 1; b) Input image 2 and c) Final fused image

pixel in specific region until constructing GLCM for each region in all input texture images and these regions are related to segments discovered in previous step for IF image. After constructing GLCM matrix many features can be calculated from this matrix such as angular second moment, contrast, inverse difference moment, ..., two of these features selected in the proposed system, they are contrast and entropy:

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

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

where, L is number of gray level in the image.as illustrated in Fig. 6. Then we selected each region from specific input image that has best value of these features and merge these regions until constructing final fused image as a result of the previous steps of the region fusion method as illustrated in Fig. 7.

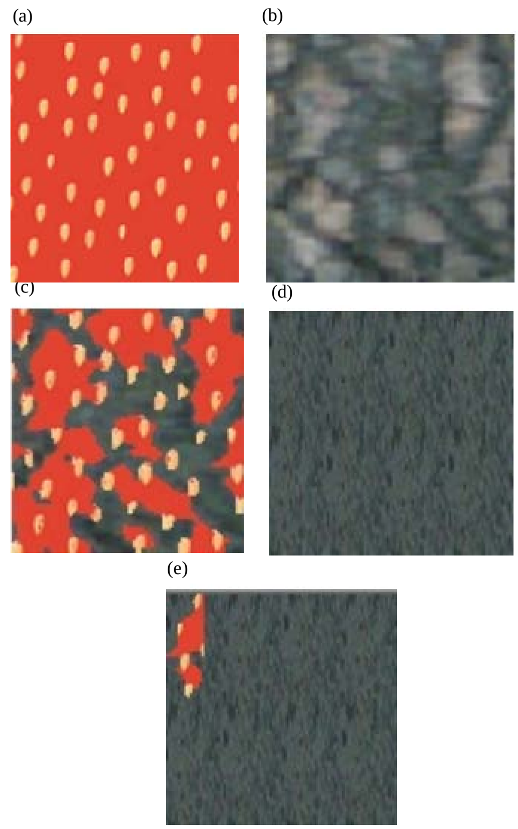

Fig. 8: Segment transformed to left up corner of background image: a) Input image 1; b) Input image 2; c) Final fused image; d) Background and e) Segment 10

The traditional fusion method stopped and finished at this step but the proposed fusion methods select suitable place (triangle of mesh) to each segment if there are compatible in size between them. The selecting triangle can be decided depending on many compatible features like direction, max length in all 3 directions (x-z) and complexity of each triangle.

Texture mapping: In this stage of the proposed system the background initially selected then each segment transformed to left up corner of background image as illustrated in Fig. 8.

This stage consist of two main steps, testing inside/outside of each point and finding which pixel corresponding to this point of the triangle by applying Barycentric interpolation for the points and then add light effects by locating light sources. If pointes Po_1-Po_3 are triangle points, Then, any point P in the plane can be explained by:

$$P = u \times po_1 + v \times po_2 + w \times po_3 \quad (5)$$

The values (u, v, w) have values <1 and they summation is 1 and if they are all >0, then point p is inside the triangle. Each point divides any triangle into three sub triangles as illustrated in Fig. 9:

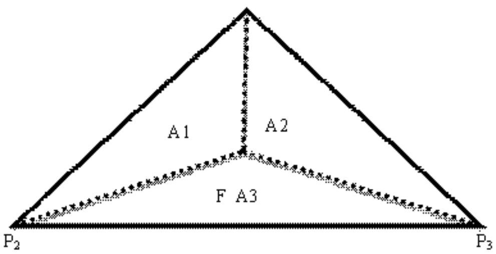

Fig. 9: Barycentric coordinates

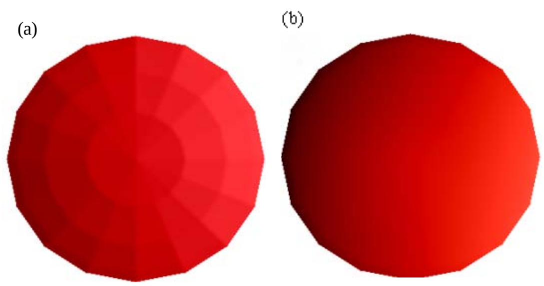

Fig. 10: Light effect on object realism: a) Flat effect and b) Eenhanced effect

$$u = \frac{\text{Area of } \Delta pp_2p_3}{A}, \quad v = \frac{\text{Area of } \Delta pp_3p_1}{A}, \quad w = \frac{\text{Area of } \Delta pp_1p_2}{A} \quad (6)$$

Lighting: Light in three dimensions environment makes objects more factual, the proposed system used Lambertian law that depend on cosine of angle (θ) between normal and light direction. Simple light and shadow are suitable in providing three-dimensional effects to the object or scene, as illustrated in Fig. 10. As the angle (θ) in specific point increase, the light at that point drops off:

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

Where:

N = The normal of the triangle
L = The direction from the light to the point

The results of light may be enhanced by taking the average of normal of each point shared between any number of triangles to avoid edges between mesh parts and make the object actual as illustrated in Fig. 10.

RESULTS AND DISCUSSION

The proposed system will be tested and the following results will be founded where represent light position (Fig. 11-13).

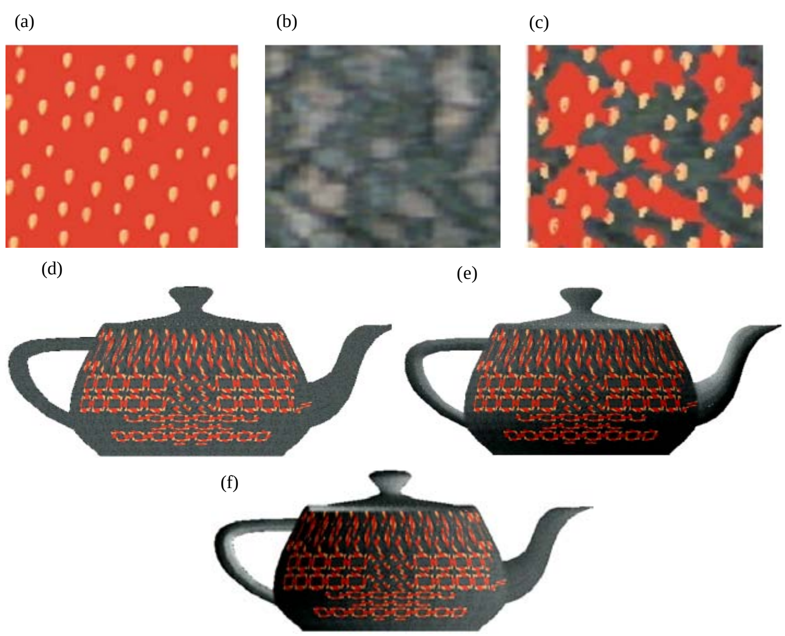

Fig. 11: Example1 results: a) Texture 1; b) Texture 2; c) Fused image; d) Image; e) Light 1 effect and f, b) Light 2

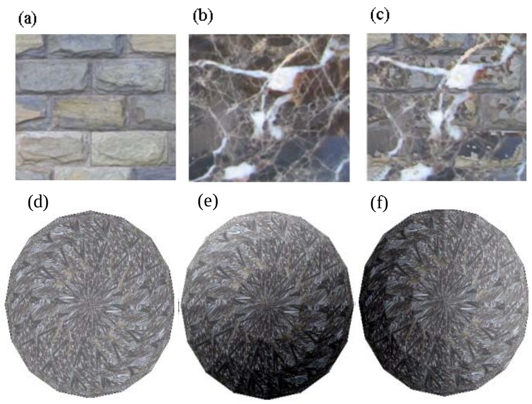

Fig. 12: Example 2 results: a) Texture 1; b) Texture 2; c) Fused image; d) Image; e) Light 1 effect and f, b) Light 2 effect

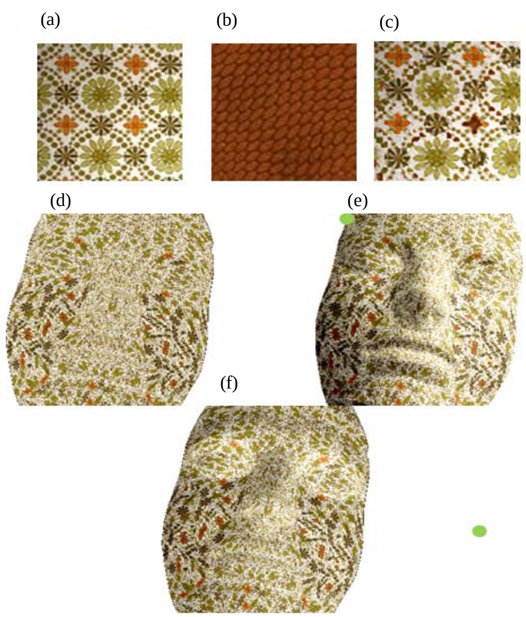

Fig. 13: Example 3 results: a) Texture 1; b) Texture 2; c) Fused image; d) Image; e) Light 1 effect and f, b) Light 2 effect

CONCLUSION

After running the system of extended fusion operation we can discover that the novel extended fusion process not necessary mapped all region in the fused texture image and this process depend on the selected compatible features like area of triangle from mesh and segment area from texture image and segments with specific area will be mapped only and this process also reflect the number of similar sets of triangles in the mesh. The fusion method is adaptive method because mapping operation depend on specific features and this process may be done or not depending on these features.

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