

Gradient Method to Construct 3D Digital Image of a 2D Digital Image

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Abstract: 3D vision of image has become the area of interest of many researchers. Numerous image processing algorithms have been developed over the past decade. This work covers a novel method of converting 2D image to 3D image. 3D imaging provides very detailed and valuable information. The approach effectively incorporates visually prominent boundaries, prominence measure of pixels and local color & region gestures. The proposed algorithm uses the method of gradient that would be the direction of uphill. The gradient has a direction and a magnitude; it is natural to encode this information in a vector. The length of this vector provides the magnitude of the gradient. Vector can be used to provide height/depth of an image, that generates 3D image of an original 2D digital image.

Keywords: 3D; 2D; reconstruction; gradient; displacement map

1. Introduction

3D modeling is a technology through which three dimensional models of any given object can be created. The technology is quite essential for several reasons. 3D models are very meticulous and provide immense details about each element, which help in communicating the information with ease and allow viewers to understand design in lot better way.

Product design process has become easy with 3D modeling as we can create three dimensional models virtually for any object no matter how gigantic or micro it is. This very fact helps creating an exquisite design for any product (e.g. orthodontic diagnosis) [10]

3D means three-dimensional, that is, something that has width, height and depth (length). Our physical environment is three-dimensional and we move around in 3D every day. [14] Humans are able to perceive the spatial relationship between objects just by looking at them because we have 3D perception, also known as depth perception. As we look around, the retina in each eye forms a two-dimensional image of our surroundings and our brain processes these two images into a 3D visual experience. There are high expectations for the further development of three-dimensional display technology [17].

The accuracy which 3D models contain is unparalleled and no other conventional modeling or visualizing approach can be as accurate as 3D modeling.

2. Literature Review

In the field of robotics, especially AI (Artificial Intelligence) is the rapidly growing field of current century and therefore, 3D vision has become the area of interest of many researchers. The fundamental difference between 2D and 3D vision is the inclusion of the third coordinate – depth [9]. This information can be acquired by various means ranging from stereoscopy (use of two specifically aligned cameras) to laser scanning of the environment,

while each of these techniques have their own advantages and disadvantages. Another exploring field is 3D printing technology. 3D printing has been great impact in many industries such as medical science, engineering, aerospace, education and many more. [3, 15]

In industry and manufacturing, 3D vision systems provide unprecedented precision and flexibility in control, measurement and quality inspection. While these areas require different approaches to hardware construction and methods of 3D image acquisition, most of the image processing algorithms are used universally [9].

As an important part of digital image processing technology, the 3-D reconstruction technology has been widely applied in medical research, remote sensing and telemetry and virtual reality etc. [16, 18]. The technology is quite essential for several reasons. 3D models are very meticulous and provide immense details about each element, which can help in communicating the information with ease and allow viewers to understand design in lot better way. With the development of 3D applications, face recognition and facial animation [11] becomes an important component of 3D content production [4]. A multitude of computer vision based techniques reconstruct and model 3D objects or scenes from photographs or video footage captured in 2D (monocular) or 3D (stereo) [7].

This work enables us to visualized and understand the three-dimensional world behind a two-dimensional image. The overall objective of this work is, given a single image, to automatically produce a comprehensible interpretation of the depicted scene. On one level, such interpretation should include resourcefully recognizing known objects and known materials as well as their rough positions and orientations.

There are two methods that widely used in 3D reconstruction field [4, 5, 6, 9, 13]

- Stereo triangulation/ Stereo Vision
- Structure from motion

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Among the different methods of segmentation [1] two main groups are:

- Region growing methods, based on the similarities within regions, thereby providing a set of pixels with the same level of intensity,
- Edge detection based on gradient method, a result of which it is received a set of edges across which the level of intensity of pixels is different.

3. Methodology

The implementation contains some basic image processing operation [2] namely Enhancement, Segmentation, Smoothing and surface construction.

This method includes five main steps:

- (1) Image Pre-Processing
- (2) Gradient of image
- (3) Filtering
- (4) Intensity adjustment
- (5) Construct 3D surface

$$f_x = (2 + 4c)^{-1}\{f(i + 1, j) - f(i - 1, j) + c[f(i + 1, j + 1) - f(i - 1, j + 1) + f(i + 1, j - 1) - f(i - 1, j - 1)]\} \quad (1)$$

$$f_y(i, j) = (2 + 4c)^{-1}\{f(i, j + 1) - f(i, j - 1) + c[f(i + 1, j + 1) - f(i + 1, j - 1) + f(i - 1, j + 1) - f(i - 1, j - 1)]\}$$

$$\text{Where } c = \frac{(\sqrt{2}-1)}{2-\sqrt{2}}.$$

$$\nabla F = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y} \right]^T$$

The gradient magnitude and its direction are given by the following formula

$$I_G = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}, I_D = \theta = \tan^{-1}\left(\frac{\frac{\partial f}{\partial x}}{\frac{\partial f}{\partial y}}\right) \quad (2)$$

The gradient values on the border of input image are the same as in the it's inner pixels. This gradient image values (equation-2) are useful to calculate edge strength values is $\sum_{p \in \text{Edge}} \frac{\text{gradient}(p)}{N}$. Where Gradient (p) represents edge points gradient values which come from the gradient image step for all pixels (p) on the edge between every two regions, and N are the number of edge pixels.

Calculate weights for image pixels

The weight is the absolute value of the difference between the intensity of the pixel and the reference grayscale intensity specified by the scalar. Pick a reference grayscale intensity value that is representative of the object you want to segment. The weights are returned in the array I_G , which is the same size as input image F .

These steps are constructed in MATLAB using image processing algorithms [12]. MATLAB is an excellent tool to accomplish these tasks.

Image Pre-processing

Pre-processing is applied on images at the lowest level of abstraction and its aim is to reduce undesired distortions and enhance the image data which is useful and important for further processing. It is usually necessary and required for improving the performance of image processing methods like image transform, segmentation, feature extraction and fault detection. This Step is focused on filtering and intensity adjustment as pre-processing methods.

Gradient Calculations

In Image Processing, a digital image may be defined as a two-dimensional function $f(x, y)$, where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point.

The gradient defined the first partial derivative of an image and contains a measurement for the change of gray levels. The gradient values $I_G(x, y)$ of the initial segmented image were obtained using firstly the approximation of the gradient operator [8] in x, y directions (equation-1) as two 3x3 masks.

Use gradient image as a kernel operated on each element of the original image to its local neighbors, considered as a weighted kernel. using original image calculate mean weighted image (equation-3).

$$f(i, j) = \frac{\sum_{i,j} (I_G(i,j) * f(i,j))}{\sum_{i,j} I_G(i,j)} \quad (3)$$

Where

$I_G(i, j)$ is the 3x3 kernel and defined as

$$\begin{bmatrix} I_{i-1,j-1} & I_{i-1,j} & I_{i-1,j+1} \\ I_{i,j-1} & I_{i,j} & I_{i,j+1} \\ I_{i+1,j-1} & I_{i+1,j} & I_{i+1,j+1} \end{bmatrix}$$

and $f(i, j)$ is the intensity of the original image.

Filtering

Noise reduction plays an important role as the pre-processing method in image segmentation. Because of this reason, various methods have been developed and almost all of them depend on the same basic method for this task, i.e. averaging. In principle, noise is composed of distinct pixels which are clearly dissimilar in appearance with adjacent pixels and according to this knowledge; noise can be suppressed by averaging in the similar area of true image data. In fact, true image data is able to share the similarities in these averaged areas but noise in these areas is not. Therefore, this process of filtering will hold true image data efficiently undamaged and noise will decrease. Although the concept of averaging is clear, it is not easy to identify which pixels to average. Averaging of many pixels will cause the loss of detail of the image and on the contrary, averaging of too few pixels is not efficient on reducing the noise. Median filter is one of simplest and most efficient approaches to remove “impulsive” or “salt & pepper” noise and it is also well-known as “edge preserving” nonlinear filter. Median filter replaces each pixel in the image with the median of its surrounding pixels, uses a mask of odd length and sorts the pixels in the window by intensity as output.

Intensity adjustment

Improving in the image can perform as objectively (e.g. filtering) or subjectively (e.g. modifying the intensity value). Intensity adjustment is an image enhancement technique. Its purpose is to enhance the image by changing intensity value to new range. The basic tool for intensity transformations of grayscale images is function `imadjust` that it has the syntax

$g = \text{imadjust}(f, [\text{low in}; \text{high in}], [\text{low out}; \text{high out}], \text{gamma}).$

This function maps the intensity values in image f to new values in g , such as values between low in and high in map to values between low out and high out and values below low in map to low out, and those above high in map to high out. According to selection of the class f (class f is same as class g) all inputs to function `imadjust` are specified as values between 0 and 1 (double) or between 0 and 255 (uint8). Parameter gamma specifies the shape of the curve that maps the intensity values in input to create output, so if gamma is less than 1, the mapping is weighted toward higher (brighter) output values, if gamma is greater than 1, the mapping is weighted toward lower (darker) output values and if gamma is equal to 1, the mapping is linear.

Construct 3D Surface

Displacement mapping is a computer graphics technique using a (procedural-) texture- or height map to cause an effect where the actual geometric position of points over the textured surface are displaced, often along the local surface normal, according to the value the texture function evaluates to at each point on the surface. It gives surfaces a

great sense of depth and detail, permitting in particular self-occlusion, self-shadowing and silhouettes.

Basic idea behind this concept is to construct a polygonal “mesh” based on the intensity values of pixels in an image. That is, read in a bitmapped image and use the brightness of each pixel to generate and place triangles.

First of all, consider a 2D picture, color or greyscale. We'll be going through this image a few pixels at a time, building triangles as we go.

Take a small square of four pixels from this image. Each one has an X and Y coordinate, taken straight off the image. The lower left pixel is (0,0) and the upper right is (1,1). Our goal is to generate two triangles in 3D space from these four pixels. In the diagram below, each of our four pixels is marked as an 'x' and we can draw two triangles.

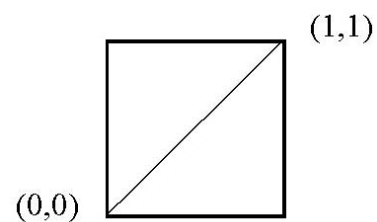


Figure 1: Four pixels' coordinate

Each pixel has an X and Y already. So, we can already write down the vertices for two 2D triangles:

Triangle 1: (0,0) (0,1) (1,1) and Triangle 2: (0,0) (1,1) (1,0)

Now, we need to turn these 2D coordinates into 3D coordinates, and for that we just need a Z value for each pixel. We take each of our four pixels and calculate its brightness. We use this brightness, scaled into some appropriate range, as the Z value.

A square of four pixels and calculate the intensity of each pixel. Then, use these four intensity values as the four Z coordinates. we have two triangles in 3D space generated from four pixels. Move over one square in the image, and make two more triangles. Move over again, and repeat.

A displacement map contains one channel interpreted as a distance of displacement or “height” from the “floor” of a surface and sometimes visualized as luminance of a grayscale image, with black representing minimum height and white representing maximum height.

4. Experimental Result



Figure 2: Original image

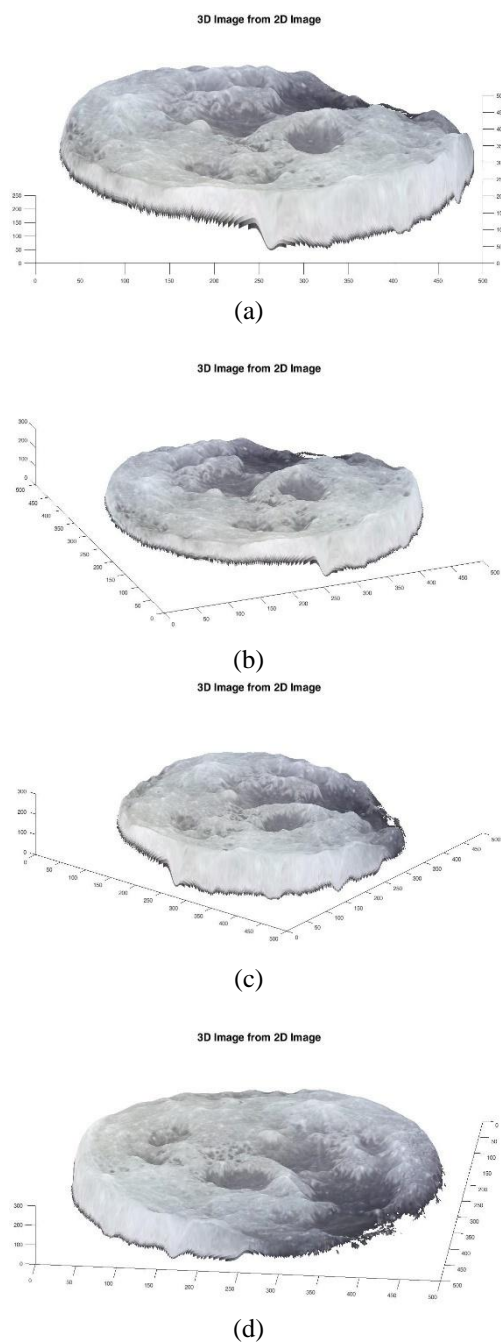


Figure 3: 3D reconstructed of original image at different orientations

5. Conclusion

3D reconstructed image is an important part of Image Processing applications in various parts in our life. The implemented 3D reconstruction approach is tested for different types of geographical images. The obtained results show a good 3D reconstruction of tested images and it shows that 3D visualization of this approach is much more interesting compared to 2D visualization. This efficient approach can be extended to different applications such as entertainment, education, training systems, real-time visualization, games and 3D printing.

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