Proposed Approach for Depth Image Enhancement

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Abstract

The world nowadays is heading toward 3D video technologies. Many applications have been proposed for processing 3D video in its different kinds. One of the 3D video kind is the 3D stereoscopic technique, which it consists of two images left and right that is combined to create 3d video. Depth image is the information of depth that is extracted from the image pair (left & right) of the 3D video. In this paper a proposed approach for extracting and enhancing the depth image is accomplished. The extraction process of the depth image from the original 3d frame is done using disparity equation and Sum of Absolute Difference (SAD) algorithm and the enhancement process is achieved using soble edge detection operator. The proposed approach gave an appearance rate of depth image reach to 88% with different random cases.

Keywords: 3D Video, Stereoscopic, Depth Image, Image Enhancement, Sobel Operator.
Objects and real things in the world can be measured in 3D (three dimensions), for instance determining width, length and height of any object. If anyone wants to look to a specific object in real world, it can be seen the height and the width of that object as a two dimensions points of view of the specific object, also the depth of that object can be perceived [1]. In the last few years, the spreading of 3D has increased in a wide range, such technology can be displayed in theaters and the audience must wear polarized glasses in order to see 3D video films [2].

The human can see objects using his/her eyes with a different perspective resulting of two views, each eye see the view from different angle, the brain combine them to create a 3D view (image). According to the above aspects a technique called 3D stereoscopic video is emergent [1]. The stereoscopic technology indicates the dual imagery obtained from viewing the scene from two point of interest with a slight offset in the
horizontal called binocular disparity to give the illusion of a depth. Each eye sees a different image that is intended to it, the left eye see the left image and the right eye see the right image. The angle of projecting the cameras on the scene is called convergence which determines where the 3D scene will appear in front of the screen or behind the screen [3].

The depth image is a depth values for color sample in the image, these values are extracted from two images that construct the 3D stereoscopic image [4]. Image enhancement is producing an image that is suitable for many applications, it is considered as one of the most mature and oldest approaches in image processing. The desire of image enhancement is to improve images in order to employ them in different applications [5].

In this paper, a practical approach for enhancing depth image of 3D stereoscopic video is proposed. The proposed approach uses Sum of Absolute Difference (SAD) to extract depth image values and sobel edge detection method to make the appearance of the objects more clearly in the depth image. The paper is organized as several section that describes the related subjects as a background theories including related works, depth image using SAD, and image enhancement in addition to the proposed approach design, implementation and test results.

2. Depth Image using Sum of Absolute Difference (SAD)
The image that is including information related to distance from surfaces of image objects to a predefined position is called the depth of the image. The difference in the horizontal coordinate of 2 matching points of the image pair (the left and right images which produce the 3d frame) referred to as disparity [6]. Matching points in an images is found by comparing an area of one image known as the reference image with a corresponding area un the target image (reference and target images are the stereoscopic image pair). Depth information is obtained by diagnosing the relative positions of matching points in the two images. Points that are close to the cameras will have bigger disparity (difference) as shown in figure (1) bellow.

![Figure (1), the disparity computations](image)

The Sum of Absolute Difference (SAD) is an algorithm based on the matching points between the images pair, it measures the similarity between the two images, it functions by taken in
consideration the absolute difference of two matching points (pixels). SAD algorithm can be used for different purposes like object recognition, motion estimation, generating of disparity map for a given stereo image [7].

The equation that computes the disparity is:

\[ D = X_L - X_R \]  

Where \( X_L \) is a point in the left image and \( X_R \) is a point in the right image

And the equation that finds the depth is SAD which it is as follows:

\[ SAD(x, y, d) = \sum_{(i,j) \in B(x,y)} |I_L(i, j) - I_R(i - d, j)| \]  

Where \( I_L \) is the left image and \( I_R \) is the right image and \( d \) is the disparity found in equation 1

3. Image Enhancement [8]

The image enhancement is considered as a process of applying techniques to employ the development and solutions of computer imaging and problems, these techniques are employed to sharpen, smooth and emphasize the feature of the images for analyzing and displaying. The applications that use image enhancement methods aim to use such methods for
either preprocessing steps to facilitate the processing of the next steps, post processing to make the final visual perception of the image more improved (as it is used in this proposed approach), or as an application itself. Enhancement techniques operate in two domains spatial domain and frequency domain, the first one manipulates the data of the pixels, the second domain modifies the components of the spectral. Each image enhancement techniques works with one of the following operations [8]:

1. **Point operations**, where the pixels are modified independently from the neighboring pixels.
2. **Mask operations**, (This operation is used in the proposed approach) where the pixels are modified depending on the values of the neighboring pixels (sub image).
3. **Global operations**, where all the values of pixels in the image are considered in the modifications.

Although the edge detection is not considered as an image enhancement tool, it is used in this paper to enhance the visual appearance of the depth image (here the Sobel operator is used).

### 3.1. Sobel Edge Detection

The edge detection is the process of finding the location of the edges in an under work image. It is considered one of the
important steps in image processing model to understand the features of a determined image. The edges consist of interesting features and contains essential information. The boundaries of a specific object is represented as locations caused by edge detection process [9].

Each edge detection is designed sensitively to each edge type. Many variables are taken into consideration to choose the type of edge detection including [10]:

- Edge orientation
- Noise environment
- Edge structure

The edge detection often is handled through using local operator, the most one operator using is the orthogonal gradient operator (OGO), the Sobel operator is considered one of the OGO. Sobel operator has two advantages [11]:

1. Because of the introductory of the average factor, Sobel has the effecting smoothing to random image noise.

2. The edge looks bright and thick because of the differential of 2 column and 2 rows, this leads to enhancing the edge elements on the two sides.

Sobel edge detection has two masks for finding edges in both directions (Vertical and Horizontal) which are represented as two matrices as follow [8]:
Vertical Edge (Y)  
\[
\begin{bmatrix}
-1 & -2 & -1 \\
0 & 0 & 0 \\
1 & 2 & 1
\end{bmatrix}
\]

Horizontal Edge (X)  
\[
\begin{bmatrix}
-1 & 0 & 1 \\
-2 & 0 & 2 \\
-1 & 0 & 1
\end{bmatrix}
\]

4. The Proposed Approach for Depth Image Enhancement

Depth image is an important feature in a 3D video/image as it has the information about how the depth of the video is seen and the changes in depth along the video frames. It is used in many applications such as Kinect and motion estimation for 3D video and compression. The proposed approach extracts the depth image by finding a matching point between the left image and right image and computing the disparity measure based on equation (1) and then applying the Sum of Absolute Difference (SAD) to compute the depth image by using equation (2) on both left and right images of stereoscopic video/image that produce the 3D stereoscopic frame.

After the depth image has been extracted from an original 3D stereoscopic frame as shown in figure(2), an edge detection masks are applied for enhancing the appearance of the depth image using Sobel edge detection operator. The proposed approach aims to enhance the depth image of the 3D video/image to make it more pleasant to look at and more clear.
to understand the depth information of the 3D video, that is for more multimedia applications which need such procedure.

Figure (2) , 3D dinosaur stereoscopic frame

5. The Design of the Proposed Approach for Depth Image Enhancement

The proposed approach for extracting depth image from 3D video frame and enhancing the appearance of it is the main objective of this proposal. Several steps must be embedded to achieve the aim of this research, these steps are organized as a formal sequence of actions system design that is each step complements the previous one, so the overall system steps represent the purpose of the proposal.

Figure (2), represents the block diagram that describes the design of the proposed approach for depth image extracting and enhancing processes, the designed block diagram consists of main steps which are listed and detailed as the following:
1. **Input 3D Stereoscopic frame**, in this step the frame that consists of two images (left and right) is inserted to the proposed system for processing.

2. **Save frame as array**, this step is divided into two sub-steps
   
   a. **Save the left image**: as mentioned previously the stereoscopic video/image consists of two images (left and right), the combination of the two images forms the 3D frame, the left image is saved in a separate array from the right image by splitting the 3D frame into two halves the first half represents the left image and the second half represents the right image.
   
   b. **Save the right image**: this step is similar to the previous one (a) which is saving the right image (the second half of the frame) in a separate array preparing it for the next step.

3. **Find matching points between the two images depend on pixel intensity**, in this step a loop is implemented to find matching points between the two halves (left and right images) depending on the pixel intensity. A pixel is chosen from the first part (left image) and a searching procedure is applied to find a match for this pixel in the second half (right image).

4. **Compute disparity between the matched points using equation (1)**, after a matching points is found in the
previous step, equation (1) is applied to find disparity between the $X$–coordinates of the two matched points

d = X_L - X_r

Where $X_L$ is the $X$–coordinates of the left matched point, $X_r$ is the $X$–coordinates of the right image and $d$ is the disparity.

5. **Apply SAD algorithm on both images to compute depth image**, the SAD algorithm is accomplished on the matched points after computing the disparity Equation (2) (steps 3 and 4) on the matched points such that is:

$$SAD(x, y, d) = \sum_{(i,j) \in F(x, y)} |I_L(i, j) - I_R(i-d, j)|$$

Where $I_L$ is the left image pixel intensity and $I_R$ is the right image pixel intensity from step 3 and $d$ is the disparity from step 4.

6. **Save the result of SAD algorithm as an array that producing depth image**,  

The results of SAD algorithm in the previous step are saved in an array representing the depth image.

7. **Apply Sobel operator**: the Sobel operator is applied for finding the edges in the two sub–steps

a. **Apply $X$ Sobel operator for finding the edge on the $X$–coordinate**, in this sub–step the $X$ Sobel operator is applied to the depth image as a $3 \times 3$ mask that is
multiplied by each pixel in the depth image to find the edges in the X-coordinate.

b. *Apply Y Sobel operator for finding the edge on the Y-coordinate*, this sub-step is similar to the previous one but in this step the mask that is applied is for finding the edges in the Y-coordinate.

8. *Enhanced frame (depth image) = X Sobel + Y Sobel*, the enhancement is achieved by adding the results of depth image after the X Sobel operator is applied to it and the results of depth image after applying the Y Sobel operator on it such that

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Enhanced image = X Sobel + Y Sobel
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Where X Sobel is the depth image after Appling the X mask and Y Sobel is the depth image after applying the Y mask on it.

9. *Display the enhanced Depth Image*, this is the final step which is displaying the resulted image after 8 consequence steps for enhancing the depth image of a 3D stereoscopic video.
6. The Proposed Approach Implementation for Depth Image Enhancement

The implementation of the proposed depth image enhancement approach is described in the algorithm bellow which represents...
the formal steps to run the proposed system as an enhancement system for the 3D stereoscopic frame to extract and enhance the appearance of the depth image to be more clear than the original extracted from the 3D frame that is extracted from 3D video.

Algorithm: Proposed Depth Image Enhancement

Input: 3D stereoscopic frame

Output: Enhanced Depth Image

Initialization:

\( H = \) frame height.

\( W = \) frame width/2.

\( Picl[H,W], \) saves the left image of the frame.

\( picr[H,W], \) saves the right image of the frame.

\( Depth[H,W], \) saves the depth image information.

\( Sobles{X}[3,3], \) the Soble mask for the \( X \)-Coordinate.

\( Sobles{Y}[3,3], \) the Soble mask for the \( Y \)-Coordinate.

\( Edge{X}[H,W], \) the depth image after applying soble–\( X \) mask.

\( Edge{Y}[H,W], \) the depth image after applying soble–\( Y \) mask.

\( Enhanced[H,W], \) the final enhanced depth image.

process
Step 1: input 3D stereoscopic frame

Step 2: divide the frame into two halves (left and right images)

Step 3: save the first half (left image) pixels intensity in picl[H,W].

Step 4: save the second half (right image) pixels intensity in picr[H,W].

Step 5: for \( l = 0 \) to \( H-1 \) do

Step 5.1 for \( J = 0 \) to \( W-1 \) do

5.1.1 if \( \text{picl}[l,J] = \text{picr}[l,J] \) then

Begin

\( d = l_L - l_R \)

\( \text{SAD} = \sum \sum (\text{picl}[l,J] - \text{picr}[l-d,J]) \)

\( \text{Depth}[l,J] = \text{SAD} \)

End

Step 6: for \( K = 0 \) to \( H-1 \) do

Step 6.1 for \( L = 0 \) to \( W-1 \) do

Begin

Step 6.1.1 \( \text{Edge}_X[x,y] = \text{Soble}_X[3,3] * \text{Depth}[x,y] \)

Step 6.1.2 \( \text{edge}_Y[x,y] = \text{Soble}_Y[3,3] * \text{Depth}[x,y] \)

End

Step 7: \( \text{Enhanced} = \text{Edge}_X[x,y] + \text{Edge}_Y[x,y] \)

Step 8: Display Enhanced Depth Image
7. Experimental Results of the Proposed Enhanced Depth Image Approach

The tested results of the proposed enhancement approach are shown in the figures (4, 5, and 6) respectively where:

Figure (4) represents the show sequence of the dinosaur frame that is (a) describes the 3D stereoscopic frame which consists left and right images, (b) after applying SAD algorithm, and (c) after applying Sobel operator.

Figure (5) represents the show sequence of the statue frame that is (a) describes the 3D stereoscopic frame which consists left and right images, (b) after applying SAD algorithm, and (c) after applying Sobel operator.

Figure (6) represents the show sequence of the space frame that is (a) describes the 3D stereoscopic frame which consists left and right images, (b) after applying SAD algorithm, and (c) after applying Sobel operator.
Figure (4), the result of the proposed enhanced depth image approach with dinosaur 3D stereoscopic frame

(a) 3D Stereoscopic frame

(b) Depth Image after applying SAD algorithm

(c) Enhanced Depth image using Sobel operator
Figure (5), the result of the proposed enhanced depth image approach with statue 3D stereoscopic frame.
Figure (6), the result of the proposed enhanced depth image approach with space
3D stereoscopic frame
8. Discussion Conclusions

From the above test results it can be seen that the proposed approach for extracting and enhancing the depth image from 3D stereoscopic frame is clearly appearance of the results which are obtained from the system implementation and are more powerful in term of the enhancing the depth image appearance by using sobel operator rather than extracting the depth image only.

The sobel operator gives the system results better obvious than the results that are extracted only using the SAD algorithm. The total test cases that are used to test the system efficiency are 33 cases, 29 cases gave efficient results (clear appearance of depth image), and only 4 cases gave depth images with some noise, that is we cannot use noise removal technique because it lead to miss some information of depth image.

According to the above discussion we can summarized the following concluded points:

1. The SAD algorithm is a very powerful technique in extracting the depth image from 3D stereoscopic frame.

2. The use of Sobel operator as an enhancement tool makes the resulted (extracted) depth image appearance more clear than without using it.
3. The proposed system is implemented with different and random cases, most of them give the better appearance results in rate reach to about 88% with random selected cases.

4. One of the interest point in this proposal is that we don’t convert the frame information to gray level in any step of the proposed system, therefore the enhanced depth image appears as colored information.

References


