High Resolution 3-D Face Modeling and Model Warping

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ABSTRACT

In this work, 3-D representations of human faces are obtained at a computer by making use of a DLP projector and a high resolution camera. The system calibration is carried out using a calibration pattern image. A colored structured light approach is adopted in this paper instead of the traditional gray-tone pattern to obtain depth information. A heuristic color correction approach is proposed in this work to improve the performance of the previous approaches. Experiments show that high resolution depth information can be extracted with this approach. Furthermore, a GUI is designed to enable user controlled modifications of the 3-D model.

Keywords

Computer vision, Structured light, 3-D Modeling, Model Warping.

1. INTRODUCTION

3-D (3-dimensional) technologies have applications in medicine, biology, unmanned control systems, and object recognition. An easy way to obtain 3-D representations of real world objects it to use structured and coded light [1].

Laser strips can be used with a rotating mechanism to create 3-D representation of objects [2]. Another way is to form a structured light using a projector and capture this pattern using a camera. The advantage of the later approach is that it does not require any rotating mechanism to obtain the 3-D model. Thus, compact and low-cost devices that are able to create 3-D models can be designed using this approach.

In this work, a low-cost and efficient 3-D modeling and modification system is designed similar to [3] with an enhanced color correction approach novel to this work. Furthermore, a graphical user interface is designed to enable user to make modifications on the model obtained in the computer.

2. 3-D MODELLING SYSTEM

The main idea of the 3-D modeling system used in this work is to follow changes in the reflections of the projected structured light. This idea is depicted in Fig. 1(a).

2.1. Hardware

The system used for 3-D model creation is composed of three main components: projector, camera and computer. A typical placement of these components is shown in Fig 1(b). The system is controlled by the computer. Our setup consists of a projector that has a resolution of 1024x768 pixels, 3000 ANSI lumens of brightness, a camera which is capable of capturing images at 12Mpixel and notebook computer which controls the whole system.
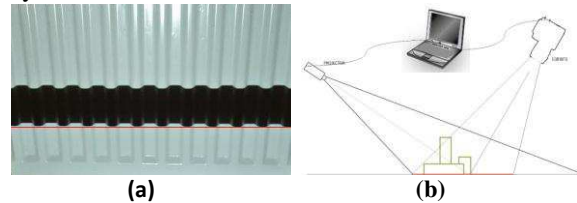

Fig.1: (a) 3-D scanning using structured light approach, (b) A typical placement of components used in the 3-D scanning system.

2.2. 3-D Model Creation Method

Calibration plays an important role to find the relation between the real word and 3-D world created on computer [4]. The calibration process can also compensate for errors originated from the optics.

Since a high resolution camera is utilized to capture images the method used for the extraction of the depth information has to be computationally efficient to process the high amount of data. Thus, a special structured light pattern has to be chosen so that less computation will be required for separation of the strips. The pattern used in this work is shown in Fig 2(a) [3]. Fig. 2(b-c) shows a raw test image

and its structured light projected form.

After obtaining the image as in Fig 2(c) the next step is to determine the face area. We used user supervision at this stage for simplicity. General framework of the proposed 3-D modeling approach is depicted in Fig. 3(a) [3]. The image obtained after the face selection process is given in Fig. 3(b).
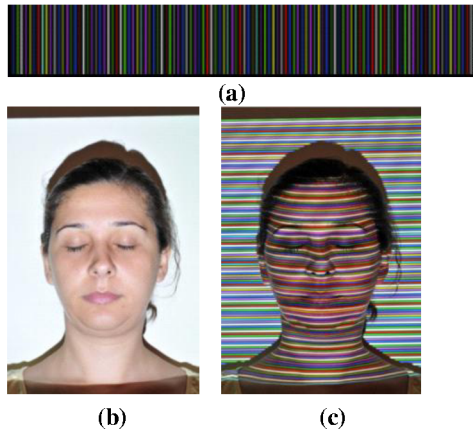
Fig. 2: (a) Color pattern used for 3-D model creation (rotated by 90°) [3], (b) Original image (used for texture information), (c) Structured light projected form of (b).
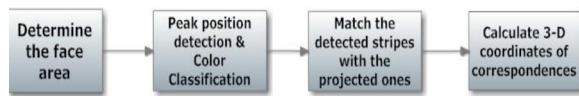

(a)

(b)

Fig. 3: (a) Flowchart of the proposed method [3] (b) Image obtained after face region selection process.

A 2-D hourglass shaped low-pass filter and 1-D band-pass filter is employed successively to remove noise and facilitate easier tracking of the strips as in [3]. Note that the filtering operations not only remove the noise but also provide a more convenient image for the separation of the color strips.

The effect of filtering operations on the color peak values are shown in Fig. 4. The figure shows the color value changes in terms of RGB values for the highlighted area in Fig. 3(b). After enhancing the input image the next step is to detect color peaks in the filtered image to follow the strips. We propose to

find the peak values in a heuristic way instead of polynomial fitting used in [3].
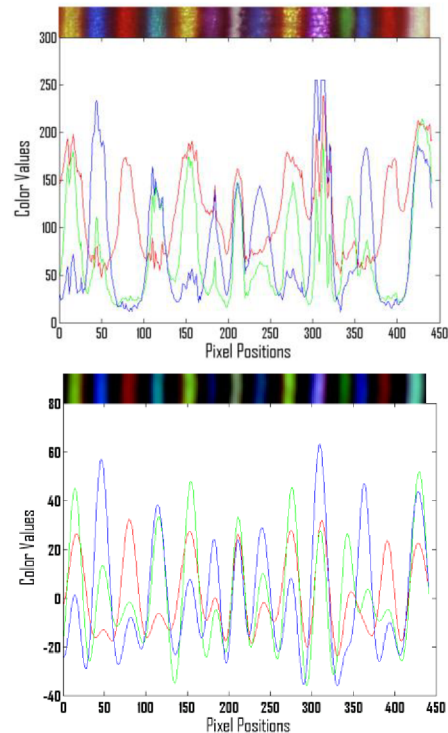

Fig. 4: The effect of filtering operations on the color peak values. Before filtering (up), After filtering (down).
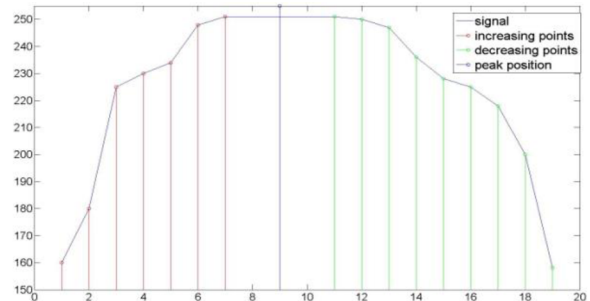

Fig. 5: Heuristic peak position determination.

Fig. 5 shows how our heuristic approach works. It firstly follows the changes of the peak values along the strip and then detects two critical points at which increase in the amplitude finishes and decrease starts.

Peak value positions are computed in a similar way for each color channel. Next, peak positions for each channel are averaged to find vertical peak color positions as in [3]. There are some misclassifications at this stage which might significantly affect quality of the final model. In [3], a k-means based line fitting method (KMeansLineFit) is utilized to eliminate misclassifications examining distributions of pixel values in RGB space (Fig. 6(a)). This method fits seven lines to the RGB space and decides the class of the pixel according to the distance between the line and the point.

Our experience has shown that when the amplitude values of pixels are below a certain value, the classification performance might be degraded. In order to improve the performance we propose to use a weighting approach before the classification stage as given below:

$$I_w = I + I_f \times w \qquad (1)$$

where (1), I, I_f, I_w, and w represent the original image, filtered image, enhanced image and weighting coefficient, respectively.

The pixel value distribution in RGB color space after the weighting operation is shown in Fig. 6 (b). As seen from this figure, distinction between the classes is more obvious. The enhanced part of the highlighted image area in Fig. 3(b) is also shown in Fig. 6 (c). The KMeansLineFit method is executed after the weighting process.
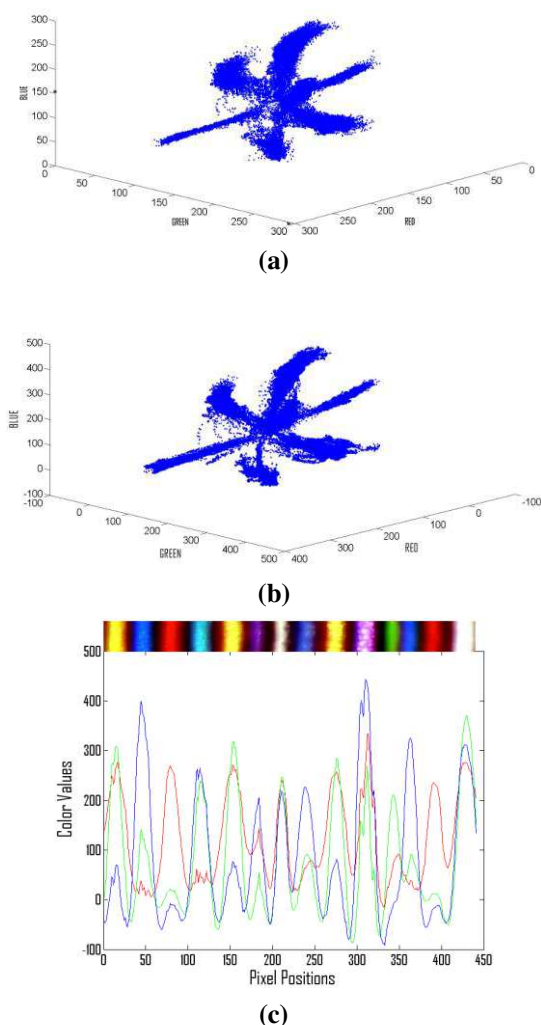

(a)

(b)

(c)

Fig. 6: (a) RGB space distribution of the pixels that corresponds to peaks in Fig 3(b). (b) Same distribution after the weighting (c) Color values after the enhancement

Although the weighting operation reduces the number of color strip misclassification, there are still some incorrect color assignments. If there is more than one color in a strip then majority voting is carried out within the strip and a fixed color is assigned to all pixels belonging to that strip. Next, strip segments that do not have any connection with other segments are examined by taking the reference strip into consideration and gaps between the segments are linearly fitted. An original image part and the corresponding color classification obtained at this step are shown in Fig. 7.

The position differences between the originally projected and observed lines are required to compute the depth. For this purpose, the reference lines that are obtained using camera-projection calibration [5] are compared to strips obtained as in Fig. 7 to extract the depth information. Depth information is depicted as 3-D form in Fig. 8.
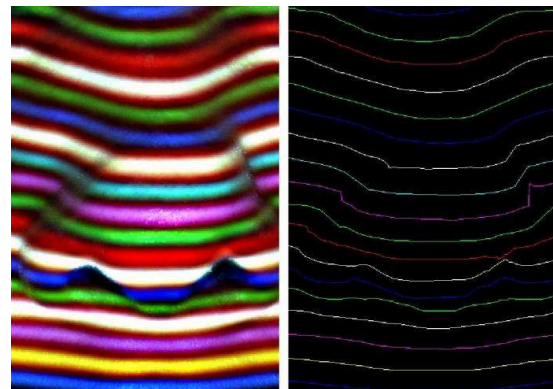

Fig. 7: Example enhanced image part and corresponding color classification of the proposed approach.
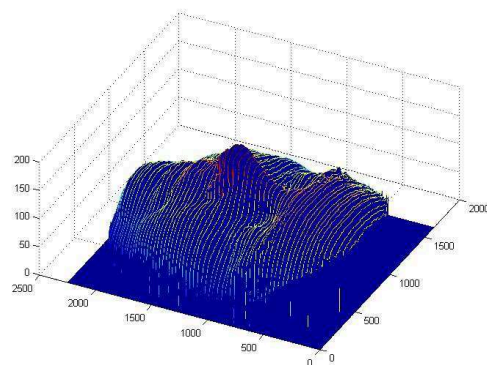

Fig 8: Representation of the extracted depth data

After the depth information is obtained the data has to be triangulated for further processing. In this work the Delaunay triangulation method [6] is used for this purpose.

2.3. 3-D Model Warping

After the triangulation process, the data can be visualized in different forms. Example visualization with texture mapping is given in Fig 9. OpenGL

software interface is commonly used in 3D applications [7-8].

One of the main purposes of this work is to make modifications on the 3-D model by means of a GUI. The modification on the model corresponds to changing some of the triangle coordinates of the model in 3D space. After the selection of the deformation area, deformation type and effect region must be defined. In our application, deformation region shape is chosen as a disk but it could be any smooth geometric shape. The effect of the deformation should decrease by distance to the deformation center. This effect is carried out by introducing a weighting coefficient.

$$X2 = X1 + k * (1 - dist / R) \qquad (2)$$

$$X2 = X1 - k / (1 - dist / R) \qquad (3)$$

In (2) and (3), $X1$, $X2$, k, and $dist$ show old and new positions of the vertex, the weighting coefficient and distance to the deformation center, respectively. The function given in (2) is used for expansion whereas the function in (3) is used for diminishing of the area. Fig. 9 shows original models (left column) and deformed model (right column) using the function in (2) and (3). Note that for example, in Fig. 9, nose of the female model is bigger than the original model.

3. CONCLUSIONS

We present a modified method for 3-D face model creation in this work. The method is based on the structured light approach and it work well for face modeling. Enhanced color correction approach presented in this work improves modeling accuracy. We also designed a graphical user interface for model modifications. Experimental results show the effectiveness of the proposed method. Additional modification operators will be considered for further work.

4. ACKNOWLEDGEMENT

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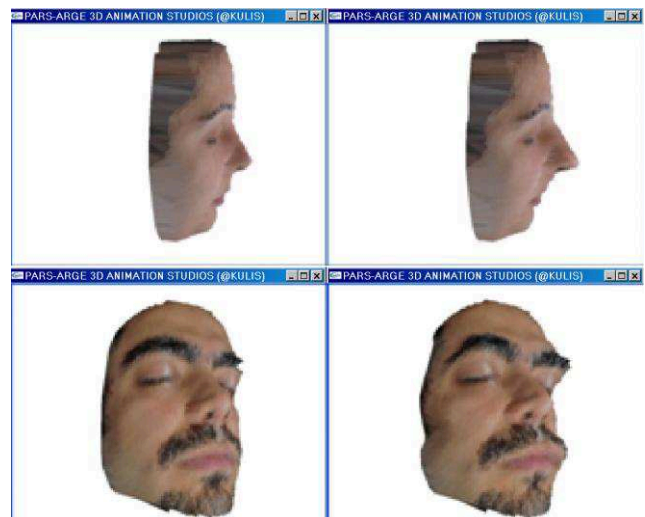[8] M. Segal and K.Akeley. The OpenGL Graphics System. A Specification (Version 2.1 - July 30, 2006)

Fig. 9: Original models (left column) and deformed models (right column)