Automatic Blemish Detection for Image Restoration of Virtual Heritage Environments[1]

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Abstract. This paper proposes a novel approach for the completion of natural scenery images, which automatically detects the blemish region in the image for restoration. This approach consists of two filtering steps and uses shape information to detect the blemish region. Then, the detected regions are marked with a specified color, so that image completion is conveniently implemented in the area we detected. We demonstrate this approach with an image database containing a variety of scenery images, especially the images or frescoes of Dunhuang, which are the relics of Chinese culture and are urgently needed to be protected and restored. The experiment results show that our approach is effective when integrated with the subsequent image completion procedure.

Keyword: image completion, blemish detection, detection filtering, virtual environment, texture synthesis

1 Introduction

Image completion, which is often named as region completion, or image inpainting, is a challenging issue in image and graphics processing, and has been emerged to be a high level understanding task of low level vision content. Image completion plays a key role in a variety of research areas, including photo-editing, artwork-repairing, movie post-production, etc. The procedure of completing missing content in images is the kernel task of image completion in this paper. The main idea of our approach is often the principle of good continuation, which consists of adding content with the information from the outside of the area to be inpainted.

Recently there have been a number of research works that bring forward some methods to solve the problem of image completion. However, most of these methods require that the portion identification should be restored with user interaction, namely users have to handle image inpainting, high scene complexity in interactive process. This is a tedious process when the database is very large. Instead, our method automatically detects most damages based on several filters, and acquires high efficiency.

Since it is difficult to select blemishes on most video frames, video inpainting uses motion estimation, shape features, and Kokaram's model [1] to detect blemishes on video. Unfortunately,

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motion estimation and Kokaram's models can not be used in blemish detection of a single photo image. Thus, we propose an approach to detect photo blemishes and optimize the finding of blemishes in random color textures [2]. In this paper, we propose a novel approach to automatic detect image blemish through several filters and mark the specified color in it for addressing image renaissance by means of structure and texture propagation afterwards. The goal of this paper is to accurately detect and localize blemishes in photos of natural scenes.

The main contribution of this paper can be summarized as follows:

(1) The strategy is similar but different from color image segmentation [3] to find fore ground objects. Our method learns to find the distinction of intensity variation and makes blemishes detection automatically.

(2) This paper is also devoted to an extension of the current features and takes advantage of shape information presented in the image in order to detect specific blemishes.

The remaining part of this paper is organized as follows: First, section 2 introduces our research background of this paper. Section 3 gives a brief overview of the entire completion procedure. We introduce how to detect the blemishes of an image automatically on the fly in detail in section 4 and section 5. Experimental results of our method are shown in section 6, Finally we give concluding remarks in section 7.

2 Research Background

The above work is being developed in the context of the National Grand Fundamental Research 973 Program of China. This project has two target applications, a virtual heritage reconstruction and automobile appearance display project. In the following sections, we describe these applications and discuss the first results of the system in use.

We briefly discuss a selection of the most relevant computer graphics/vision approaches for data capture and display. We then present a rapid overview of previous work related to the chosen application domains. The goal of our project is to reconstruct the heritage site called HEMUDU which can let the user to understand how the ancients live. The user also can participate into the virtual environments to experience the life of the ancients about 7000 years ago.

2.1. Model Reconstruction

The premise of our modeling approach is the creation of realistic 3D scenes by different methods that can be displayed in VHEs. In computer graphics, a number of Image-Based Modelling and Rendering techniques have been developed (e.g., [4], [5]). Despite recent advances (e.g., [9]), these techniques usually require special purpose display methods. Such approaches can be hard to integrate into traditional VR systems, which have numerous software components to handle the complexity of the hardware platform (stereo, tracking, different devices etc.), and are usually created with standard scene-graph APIs such as OpenGL Performer. As a result, the application of such techniques into an integrated VHE is rare. We have chosen to use a modelling-from-scanner approach (e.g., [5], or from image, ImageModeler from REALVIZ. Other forms of manual modeling using modern modeling software could potentially be used for some of the applications we examine; each approach has different tradeoffs. In the context of situated activity in a VHE, we believe that the simplicity and cost of capture from photographs, and the quality of the resulting models justifies our choice. This does not hold true for all applications (for example, where millimeter precision is required). In the long run, we believe that combinations of several different acquisition techniques should be used. For the display of vegetation, we use a mixed point-based/polygon rendering technique which allows us to handle complexity efficiently.

2.2. Display and Interaction

As VR technology becomes commonplace, there has been a proliferation of VR in fields such as design, education, and entertainment or, in other words, areas where VR applications are more easily available to and accessible by the general public. In the field of education, VEs have been developed to help teach concepts that are hard to learn [11], [12] or difficult to visualize otherwise. In design, VR has been used where conventional media are ill-suited to represent the work processes in ways that make them easy to visualize. In both cases, VR, with its immersive and interactive properties, can offer possibilities and solutions that are otherwise very difficult to obtain. For these reasons, we have chosen two application domains that relate to learning and working in VR, an archaeological reconstruction and automobile appearance display project.

Our choice has been motivated by the fact that both tasks are real-world projects that are currently in progress and in need of high-level tools and presentation means that will speedup and facilitate the work or help in better dissemination of their cause. In the first case, the Society of DUNHUANG Studies has been involved for years in display frescos and the Grottoes on which the frescos are drawn, reconstructing the archaeological site in order to make it more accessible to visitors, Additionally, the grotto-like environments can be used in a cultural heritage museum. The automobile designer, who has undertaken the development of the automobile, wishes to thoroughly evaluate the effects of the automobile on the virtual environment. Automobile appearance display can be used in designing of automobile industry, which can be reduce the cost of designing since the designer can find the bug instead of producing. We use cubic display environments called CAVE to display the frescos of DUNHUANG. These frescos are scanned form real wall of DUNHUANG, which consists of huge points data and high detail texture. For the second application, we display an outdoor complex scenes which consists of lot of objects, this objects can be from scanner or photograph or triangle model. The observer can interact with the virtual environments through a data gloves, the user can take a harpoon to fish. We use FOB(The Flock of Birds) to track the position of eyes and hand. FOB is a six degrees-of-freedom measuring device that can be configured to simultaneously track the position and orientation of multiple sensors by a transmitter. Each sensor is capable of making from 20 to 144 measurements per second of its position and orientation when the sensor is located within ± 4 feet of its transmitter. We use Cybe-Grasp to track the action of the finger, and the user can get force feedback form the objects of scenes by wearing the Cybe-Force device. By introducing viewpoint dependent display techniques the user also observe the relic in near distance.

3 Blemish Detection

Most existing image inpainting methods depend on user interaction to select blemish region for inpainting. However, user interactions initially only provide rough information and iterative interactions are needed to provide high efficiency. Thus when the image database is very large, the manual work is very tedious. Regarding this problem, we propose a blemish detection algorithm in this section. Given an input image with much blemish, our algorithm can be used to detect the blemish region, and remark it in specified color. The detection procedure can be described as follows:

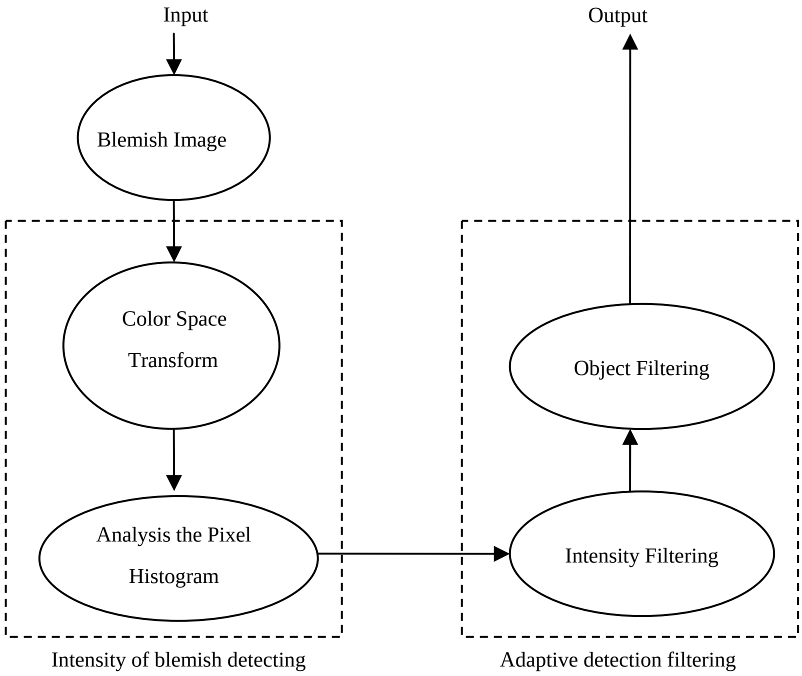

Fig. 1. The Automatic Detection of Blemish in Image Procedure

4 Intensity of Blemish Detecting

Use HSI color space instead of RGB color space which is commonly used for the reason that the first is closer to human feeling. Our algorithm to find the possible minimal intensity of a blemish area is shown as follow:

Algorithm 1: Intensity of blemish detecting

Input: image W

Output: blemish of image intensity R

Maximum length of a continuous curve L($L \geqslant 5$)

Threshold of difference of pixel T (initially =100)

Amount of pixel N (N=100)

1 Convert image W to HSI color space

2 Compute the number of pixels, w.r.t each I variation; let P_i represents the number of pixels in the i^{th} I variation, where $1 \leqslant i \leqslant 255$

3 Compute $\Delta P_i=(P_i-P_{i-1})$, if $\Delta P_i < T$, store i in an index list Q

4 Search Q and store the consecutive elements in set S, $S_i=\{R, M_i\} \in S$;
where R is the start intensity of consecutive elements,
and M_i is the length of the i^{th} consecutive elements

5 Find S_i with the maximal length M_i in the set S,
where the consecutive elements have M_i less than or equal to L

6 If no $M_i < L$ then T=T+N, goto 3; else return R

In the algorithm above, we describe the intensity of blemish detection which is the preprocessing of our image impletion approach. We consider the intensity and shape of photo blemishes instead of color attribute because the photos usually include much variety of colors and it is difficult to use the color content for our purpose.

However, we discover that the intensity variation of blemishes is usually quite smooth and steady while compared with other visual content in photos. Thus, we use the intensity in the filter above. We decrease the value of intensity from 255 to 0 at each step and record the number of pixels detected. It has been mentioned that the intensity variation of blemish is usually low. In decreasing the intensity of a photo, the blemish part will be remained while other parts will be filtered, up to an estimated intensity value. In the second filter, we compute a pixel histogram, with pixel numbers on y-axis and adjustment of I values on x-axis. This means the number of pixels detected in each I variation is recorded. The histogram is represented as a curve chart in our tool (see Figure 2). And the variance of pixel number detected between two different steps of adjustment is also calculated. If the variance is low, it means that pixels that have been detected in the last adjustment are not much affected by the present adjustment of L. And the pixels that have been detected are possible to be the pixels of blemish because of its steady intensity.

Keeping on the calculation of variance of detected pixels, a collection consisting of consecutive adjustments of I variation can be constructed. Since the variance of detected pixels is sometimes low when it has low discrimination in a step of I adjustment, the collection needs to be analyzed. Then the recorded collection has no use and the blemish can’t be detected. Thus, if the collection of adjustment contains too many passes of adjustment, we just leave it and go on to analysis the photo image. After the calculation and analysis, a set of adjustment of I variation can be found out to separate pixels of blemish part from other parts in the photo.

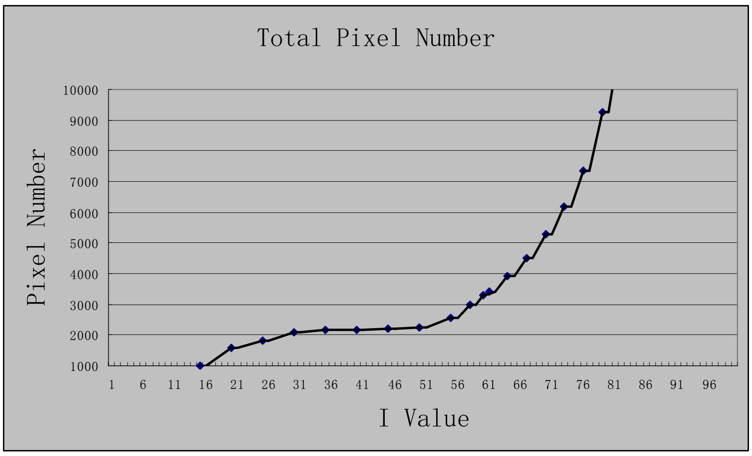

Fig. 2. Hitogram of Pixel Number

5 Adaptive detection filtering.

We propose an adaptive filtering using the intensity gained in the algorithm 1 which considers the details of object properties, to find the potential blemish objects of a photo and then to make a decision. The pseudo-code is shown in Algorithm 2:

Algorithm 2: Adaptive detection filtering

A set of objects O; $O_j=\{A_j,B_j\} \in O$, A_j and B_j are the area size and boundary of object O_j

A percentage threshold of object size Ω (50%)

A threshold of number of pixels μ (5 or 10)

A decreasing intensity of amount ε (10)

1 Store initial objects obtained from color segmentation in set O

2 Remove small objects form set O if the area of object size $A_j < \mu$

3 Use filter Opening(Closing(C)) to remove isolated objects in O

4 Copy set O to a new set Q; Let n be the number of objects in Q; Let s= δ be an initial intensity value(from the defect intensity detector)

5 Intensity Iteration: Repeat till n has no change

    For each object O_i in Q do

        If A_i decreases > Ω from last Intensity Iteration and O_i is not split then

            remove O_i from Q and update n

    Sets = s — ε

6 For each element O_j in set O not removed in Q

        Mark O_j in image C

The algorithm above will detect multiple objects. Each object O_j in an object set O has two parameters, A_j and B_j, to represent object size and object boundary, respectively. We define a threshold of object size, p. If an object size is small than the p then we remove the object from set O. Two morphological operations, opening and closing, are then used. The median filter operation with 3x3 filter windows performs isolate object detection and elimination. The adjustment of I is achieved by decreasing the value of I from δ to carry out the blemish object to be detect by an intensity value of 5 at each step. In each step of adjustment, we record the size and locations of object O_j detected in a new set Q. The parameter n is a number of the objects in set Q. The new set Q is for intensity iteration while the original set O is used as a reference. In intensity iteration, an object can be split. The size of object (includes split objects) can be reduced. However, the center of the object is not likely to be altered. To tell whether split objects belong to an original object, we compare the center of split object against the boundary of the original object. It is important to keep track of which split object belong to an original object since we calculate the decreasing rate of area. If the decreasing rate is high, the object is not likely to be a blemish. After several intensity iterations, the object left in Q are blemishes. We mark the original blemish objects in O on the photo.

6 Experiments and Results

Users can apply our method to their own private photos. In our experiments, we have applied this method to the image of Mogao Grottoes of Dunhuang of Chinese culture relic. We set the threshold of object size to 10 pixels. Of course there will be some blemish region left not detected.

We have been making the digitization of No.158 Mogao Grotto of Dunhuang of China. There are three sculptures in this grotto. The length of the biggest is 15.70 meter, and the other two is about 5 meter. The 3D model of the cave and sculptures were scanned by a 3PrdPTech Deltasphere 3000 laser range scanner. The adopted texture images in the experiment were acquired by a KODAK DCS 660C camera. A 14 mm, a 35 mm and a 60 mm lens had been used.

We show some original acquired images of a painted sculpture's head and the detected results in figure 3. At first we select the face of the sculpture as our test region in order to make our detection more precisely, however we exclude the eyes and the mouth which are detected. The blemish areas in the face are marked with red color. The upper row presents original texture images, and the lower row presents the detected texture images. We can see our approach is effective from the contrast between both of them. And we also set 5 groups of images with different point of view to be compared for better reference.

Fig. 3. Results of Blemish Detection of a Sculpture's Head

The final digitization results of those three sculptures using our detection approach and image inpainting processing are shown in figure 4. The laying sculpture has a gray color appearance, so we render this model with lighter illumination to achieve a good visual result. We can discover that the faces of the sculptures of Buddha are very clean and there is no blemish to destroy the whole effects.

Fig. 4. Effect of Three Sculptures

Combining our method proposed in this paper with our image completion algorithms, the texture images are inpainted very well, and our work is appreciated by persons who gain strong impressions by the effect of the project. The 3-dimension scene of Mogao Grottoes of Dunhuang containing the three sculptures of Buddha is shown as figure 5:

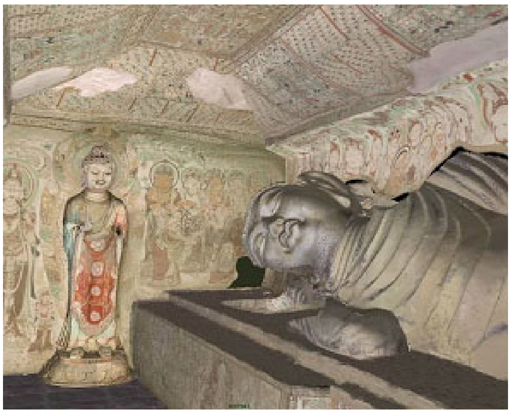

Fig. 5. Results of Our Project

7 Conclusions

We know there are many nice algorithm of image completion, however, those algorithm need user to select the blemish region to be inpainted, which will lead to neglect some small blemishes. In this paper, we have presented an automatic approach to detect the blemish area for image completion. However, if the photo is more complexity, we can split the photo into multiple portions before the regions containing blemishes are detected, and then apply our method to each portion individually.

Our algorithm was validated to be practical. With the assistance of this algorithm, we are able to restore many rarity photos of cultural relic, such as the photos of Dunhuang above. And to the very old photos, our algorithm also gives an effective way to solve that.

References

1. Vittoria Bruni and Domenico Vitulano, “A generalized model for scratch detection,” IEEE Transactions on Image Processing, 13(1), January 2004, pp. 44-50.
2. K. Y. Song, J. Kittler and M. Petrou, “Defect detection in random colour textures,” Image and Vision Computing, 14(9), october 1996, pp. 667-683.
3. Swee-Seong Wong and Wee Kheng Leow, “Color segmentation and figure-ground segregation of natural images,” in Proceedings on International Conference on Image Processing, ICIP’02, 2002, pp. 120-123.
4. GORTLER S. J., GRZESZCZUK R., SZELISKI R., COHEN M. F.: The lumigraph. In SIGGRAPH 96 Conference Proc. (Aug. 1996), Annual Conference Series, pp. 43–54. 1, 2
5. DEBEVEC P., TAYLOR C., MALIK J.: Modeling and rendering architecture from photographs: A hybrid geometry- and image-based approach. In Proc.SIGGRAPH 96 (August 1996), pp. 11–20. 1, 2, 3, 4
6. Chamberlain,xB., DeRose, T., Lischinski, D., Salesin, D., Snyder, J.: Fast Rendering of Complex environments Using a Spatial Hierarchy.In: Proc. Graphics Interface’96, pp132-141, 1996.
7. Sudarsky, O., Gotsman, C.: Output-Sensitive Visibility Algorithms for Dynamic Scenes with Applications to Virtual Reality. In: Computer Graphics Forum (EUROGRAPHICS 96 Proceedings), 15 (3), 249-258, 1996.
8. A. Machi, F. Collura, “Accurate spatio-temporal restoration of compact single frame defects in aged motion picture,” in Proceedings on 12th International Conference on Image Analysis and Processing, 2003., 17-19 Sept. 2003, pp. 454-459.
9. BUEHLER C., BOSSE M., MCMILLAN L., GORTLER S. J., COHEN M. F. Unstructured Lumigraph Rendering, SIGGRAPH 2001, Computer Graphics Proc.2001, Annual Conference Series, pp. 425–432. 1, 2
10. L. Joyeux, 0. Buisson, B. Besserer, S. Boukir, “Detection and removal of line scratches in motion picture films,” IEEE Computer Society Conference on Computer Vision and Pattern Recognition, June 23-25, 1999, pp. 548-553.
11. ROUSSOS M., JOHNSON A. E., MOHER T. G., LEIGH J., VASILAKIS C. A., BARNES C. R.: Learning and building together in an immersive virtual world. PRESENCE journal 8, 3 (June 1999), 247–263. 2
12. BARAB S. A., HAY K., BARNETT M. G.: Virtual solar system project: Building understanding through model building. In Annual Meeting of the American Educational Research Association (Montreal, Canada,April 1999), AERA. 2, 8