Study of System Model of Image Inpainting Combining Subjective Estimation and Impersonal Estimation

Weilan Wang, Huaming Liu

***Abstract*—Aiming at the present condition of the filed of digital image inpainting lack a "all-purpose" or a general algorithm to modify various damaged image, in order to inpaint more types of damaged images in different domains, a new system model of image inpainting is proposed in this paper. Then performance inpainting, the system model will give some information, which consists of the satisfaction of subjective and impersonal estimation of the inpainted results, the used algorithm and so on. Thus, user can select the better-suited algorithm to be inpainted image by referring this information. At the same time, the system model has the function of self-learning.**

***Index Terms*—Image inpainting, subjective estimation and impersonality estimation, system model of image inpainting, self-learning.**

I. Introduction

Digital image inpainting is an important issue in the domain of image restoration and an international interesting research topic in recent years. A lot of papers on image inpainting were published. Although the presented algorithms to modify damaged regions of image had their merits, they only had some specific aims and at present there isn't a universal algorithm model of "guarantee to cure all diseases" and it is not an easy matter. The chief reason for the problem is that the segmentation of image is still a difficult issue due to the segmentation algorithms are some particular question- oriented at present, and the damaged regions of image must be segmented before inpainted. Segmentation will first affect the results of inpainting. Therefore, it is more difficult to get a universal algorithm to solve all of the problems. We attempt to design a Thangka image inpainting system which can inpaint different kinds of damaged Thangka image, which is a more powerful image inpainting system than the single algorithm's system on the basis of previous work [6][7][8]. This system, in which integrated various inpainting algorithms, can inpaint various kinds of damaged image, after inpainted, the results of evaluation are stored in database for different algorithms, the results include subjective estimation and impersonal estimation. At the some time the classified results are also recoded to database about subjective classification and impersonal classification to type of damaged region of image. Thus the most suitable algorithm to each category of damaged region can be found. The system model also has the function of self-learning in the practical inpainting process, it is convenient to provide decision support for users while system modifying an image.

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Weilan Wang was with School of Computer Science and Information Engineering , Northwest University for Nationalities, Lanzhou, Gansu Province,730030 China; e-mail:wangweilan@xbmu.edu.cn).

Huaming Liu was with School of Computer and Information, Fuyang Normal College, Anhui Province, 236029 China; e-mail: liuhuaming888@126.com

II. Quality Evaluation of Image Inpainting

Generally speaking, the inpainted image is not every bit as good as the original, thus the differences in the size will be evidence to appraise the quality of image inpainting. There are two methods of evaluating the quality of image inpainted: subjective estimation and impersonal estimation. Where impersonal estimation consists of comparative analysis method of Peak Signal to Noise Ratio （PSNR）and color difference.

A. Subjective estimation

We can say that the effectiveness of an inpainting algorithm is satisfactory depend on whether the inpainted image is very natural and without the trail of inpainted in subjectivity estimation of human eyes.

B. Impersonal estimation

(1) PSNR method

The value of PSNR (Peak Signal to Noise Ratio) is defined as follows:

$$\mathrm{PSNR}=10\log\left(\frac{255^2}{\mathrm{MSE}}\right) \qquad (1\text{-}1)$$

$$MSE=\frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left(A(i,j)-\hat{A}(i,j)\right)^2}{M\times N} \qquad (1\text{-}2)$$

Where MSE denote the Mean Square Error of pixel value of two images corresponding the pixel points; MxN indicates the size of image, namely numbers of pixel point; $A(i,j)$ and $\hat{A}(i,j)$ are pixel value of point (i,j) of the original region and the inpainted region.

If the value of PSNR is more, the loss of image is less, and namely the image will be better inpainted by the formula (1-1) and (1-2).

(2) The method of chromatic aberration

The display use RGB color space in display of digital image, and color mode is CIELan space of color difference, so color space need to conversion in order to calculation the chromatic aberration. The formula as follows (1-3) and (1-4):

$$\begin{cases} \mathrm{X} = 0.5164R + 0.2789G + 0.1762B \\ Y = 0.2963R + 0.6192G + 0.0845B \\ Z = 0.0339R + 0.1426G + 1.0166B \end{cases} \quad (1\text{-}3)$$

$$\begin{cases} \mathrm{L} = 116(Y - Y_0)^{1/3} - 16 \\ a = 500[(X/\mathrm{X}_0)^{1/3} - (Y - Y_0)^{1/3}] \qquad Y/Y_0 > 0.01 \\ b = 200[(Y - Y_0)^{1/3} - (Z/Z_0)^{1/3}] \end{cases} \quad (1\text{-}4)$$

Where X,Y and Z is tristimulus values; X_0、Y_0、Z_0 is tristimulus values of CIE, here, use light sources of D65 ($\mathrm{X}_0, \mathrm{Y}_0, \mathrm{Z}_0$ equal 95.05, 100, 108.9 respectively). L denotes psychological lightness, a and b denotes psychological chrominance respectively.

The computation formula of chromatic aberration for color space of uniformity of CIE Lab is (1-5):

$$\Delta\mathrm{E} = \sqrt{(\Delta L)^2 + (\Delta\alpha)^2 + (\Delta b)^2} \quad (1\text{-}5)$$

where ΔL denote brightness difference can be compute by the formula (1-6).

$$\Delta L = L_1 - L_2 \quad (1\text{-}6)$$

Δa and Δb denote chromatic aberration which can be computed by the (1-7）

$$\begin{aligned} \Delta a &= a_1 - a_2 \\ \Delta a &= b_1 - b_2 \end{aligned} \quad (1\text{-}7)$$

$L_1 > L_2$ illuminate that color 1 is shallow than color 2, brightness higher; $L_1 < L_2$ represent that color 1 is fuscous than color 2, brightness lower. $a_1 > a_2$ show that color 1 is slanting red than color 2 ; $a_1 < a_2$ show that color 1 is slanting green than color 2. $b_1 > b_2$ denote color 1slanting yellow than color 2; $b_1 < b_2$ indicates color 1 is slanting blue than color 2.

When the inpainted image are appraised in our research, $\Delta E'$ indicate the mean value chromatic aberration of full pixels which are the damaged region and after inpainted region, the size of $\Delta E'$ will show the effect of inpainting. The calculation of $\Delta E'$ is (1-9).

The size of $\Delta E'$ will be employed to estimate the effect of inpainting, $\Delta\mathrm{E}_1(i, j)$ and $\Delta\mathrm{E}_2(i, j)$ is all of pixels' chromatic aberration in front and behind of inpainting for the damaged region of the image. Smaller the value $\Delta E'$ is, more effective the inpainting is, as shown in formula (1-9)

$$\Delta E' = \frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left(\Delta E_1(i, j) - \Delta E_2(i, j)\right)}{M \times N} \quad (1\text{-}9)$$

III. System Model of Inpainting

In order to understand the system model of inpainting proposed in this paper, we first illuminate the sort of damaged image, and take damaged Thangka image as examples. The criterion of classification varies with the individual, and classification of damaged image in other fields could differ from each other, such as remote sensing image, medical image, etc. these do not impact the proposed system model of inpainting.

A. The category of damaged Thangka image

Damaged Thangka image can be classified into 4 classifications.

(1) Crease-Thangka

Fig 1. Crease-Thangka

Fig 2. Rip-Thangka

The crease, such as the white region in Fig 1, usually it was worked due to inadequate safekeeping.

(2) Rip-Thangka

Damaged region is caused by natural environment, that color break off from the damaged part, and the damage region is a very thin gap, the color of image is degraded as shown in Fig 2.

(3) The types of the damaged patch

The damaged image as Fig 3 show, there are 3 damaged patches, each of which has characteristic itself. The damaged images can be classified into 3 types: smooth patch, edge patch and texture patch (3 white parts from the above, below to right side are smooth patch, texture patch and edge patch respectively in Fig 3), by the information surround those patches. Smooth patch, the characteristics of such patch is: single color, gray varies slow, variety of gray range is small; Edge patch, the characteristics are, the gray varies fast, gray range is large, and deviation value is large, etc. ; Texture patch, gray distribution of texture region commonly have certain periodicity, and there are some approximately same structure in texture area any place. Some time, damaged regions are comparative complex since they could belong to single-type or multi-type. Therefore the classification of these types is also comparative difficulty, but we can adopt inpainting algorithm in single damaged region according to its type.

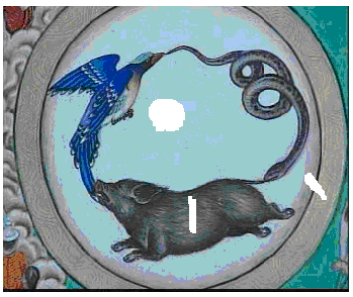

Fig 3. Smooth patch, texture patch and edge patch

(4) Spot-Thangka

There are large numbers of damaged regions, different shape and size, and area is not especially big as shown in Fig 4.

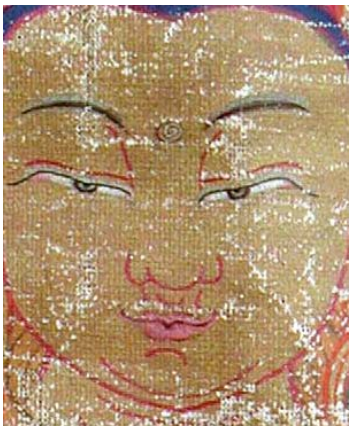

Fig 4. Spot-Thangka

(5) The key region be lose

The damaged part is a key region that is exclusive in the image, this bring huge difficulty for image inpainting, the full region of mouth missing as shown in Fig 5 .

Fig 5. The key region be lose

We only give 5 categories of damaged Thangka image as examples, researcher can process classification by practical cases. There is still some damaged image that damaged cases are comparative complexity, its inpaint to need semantic knowledge; they are difficult problem in the domain of image inpainting.

B. *Inpainting algorithms*

At present mainly two classifying-techniques can be found in the literature related to digital image inpainting.

The first one deals with the small-scale deficient of digital image inpainting techniques. The technique was introduced into image processing by Marcelo Bertalmio, Guillermo Sapiro,Vicent Caselles and Coloma Bellester [1], using marginal information of damaged region, and essentially this is an inpainting algorithm base on partial differential equation (PDE). Another is image inpainting based on variational method of the geometric image models.

The second one is image completion based on texture synthesis fill-in the large damaged region. This technique includes two methods: one is to decompose image into structure part and texture part, where use inpainting algorithm to inpaint structure part, and use the method of texture synthesis fill-in texture part [2][3]; another is texture synthesis technique basing on patch, which selects a pixel in the border of the to be inpainted region, take the point as center, select a proper texture patch in size by texture characteristic of the image, then look for the most similar texture matching patches around to be painted region to replace the patch.[4][5].

C. *System model of image inpainting*

In view of present situation of image inpainting, we attempt to solve the drawback of all kinds of algorithms, to inpaint more classes of damaged image and generate high quality results, thus novel system model of image inpainting are proposed.

(1) The structure system model of image inpainting

Take Thangka image of damaged as an illustration, damaged image are classified 5 classifications by user's knowledge as 3.1 section described. First, for the input image, we need to confirm what category of object this damaged image is, parameter v_1 denote category of damaged image in the system of subjective and impersonal estimation integrated. The detecting algorithm of damaged region will be utilized, the statistical information of proportion of damaged regions for texture patches, edge patches and smooth patches are indicated by v_2, v_3 and v_4 respectively, and $\sum_{i=2}^{4} v_i = 1$, $v_i \in [0,1], i = 2,3,4$.

The system will modify the damaged regions after the damaged region of Thangka image are segmented. The methods of inpainting can be one or more algorithms, for the proposed model, integrated algorithms the more the better, ultimately the power of inpainting different damaged image for each algorithm will be statistical calculated. The system structure model of image inpainting shown in Fig 6.

After inpainting the damaged regions, the system adopt the method of subjective estimation and impersonal estimation, finally receive two parameters v_7 and v_8, which present the inpainted effect, where $v_i \in [0,1], i = 7,8$ and 0 denote worst, 1 denote best. v_6 is used storage the serial number of one or more algorithms by order of the used

algorithms. The variety of v_7 and v_8 will dependent the variety of v_6.

(2) The training of system model

First，the system need to train use damaged image, finally the statistic results of different algorithms to be used to different type damaged regions and variety inpainted images are stored database, when user use the system to inpaint the damaged images again, these statistic information are fed back to user or researcher, so that supply decision-making.

For example, suppose that a damaged image will be inpainted. If a series of algorithms is used, a good effect is gained, we suppose that the series of algorithms is 2-3-5; if another series of algorithms that is 2-4-8-1 is used, then a results series will generate. More combination of series of algorithms may develop. So it is a questions that is worth considering that how to select a series of algorithms. Where, a series of algorithms may be regarded as a route of algorithm.

(3) Select the series of algorithms

Sometimes the result of inpainting is satisfactory when using only one algorithm. In these cases we do not need to select the series of algorithms. We can compare the result of inpainting and take subjective estimation and impersonal estimation for each algorithm, the results of the estimation will be recorded in the character database of results of inpainting in detail.

If the result of inpainting is not satisfactory when using single algorithm, here the series of algorithms should be a better choice. The choice of the series of algorithms is very important, because it will immediately impact the result of inpainting. Therefore it is necessary to have a great detailed analysis for the series of algorithms in order to use less series of algorithms (the number of the series of algorithms is few) and less number of the series of algorithms (the number of algorithm route).

The series of algorithms will be adopted when modify a damaged image by using different algorithms, and at the same time subjective estimation and impersonal estimation are obtained, and if two integrated estimation reach the requested degree; Otherwise, the algorithms will be abandoned, the system will return to the previous inpainting results, and select another algorithm. The detailed content of the algorithm is as follows:

Step 1. Open an image to be inpainted, subjectively judge its label of classification, simultaneity calculate the values of v_2, v_3 and v_4 of damaged regions of texture patch, edge patch and smooth patch, and the acreage v_5 of damaged regions.

Step 2. Select one algorithm and analyze its degree of excellence by the hint of system. Here, suppose that algorithm 2 is selected, and then employ the algorithm to inpaint the damaged image.

Step 3. Do subjective estimation and impersonal estimation to the result of inpainting in Step 2, and make the decision that whether or not use the previous algorithm in

Step 2: if the result of inpanting is not satisfactory, then give away the algorithm and return to previous state of inpainted, perform Step 2 again and select another algorithm to continue execution; if the result of inpanting is acceptable, then reserve the algorithm and select another algorithm to continue execution.

Step 4. Repeat the Step 2 and the Step 3, until get a satisfactory result of inpainting, and then a series of algorithms are created, store the series to v_6, ultimately put $v_i, i = 1,2,...,8$ in character database.

Step 5. Repeat the Step 1, Step 2, Step 3 and Step 4, ultimately create another series of algorithms. Repeat the step, several series of algorithm will be created.

Step 6. Compare the several series of algorithms, find the optimum route of algorithm.

(4) Self-learning of system model

The performance of system model is independent train samples of damaged image. With the image to be inpainted abundance, system's the hint information of results of inpainting for different damage image will be more abundant, more perfect and valuable information will be provided by the system. Therefore, the system has self-learning function and will have intelligent information to hint for users. Such systems are few for the moment, because this is a practical requirement of complex damaged image inpainting, however. In addition, user can update or translates the characteristic database of results of inpainting of present system to a new characteristic of itself. Classification of damaged image standard must is consistent in this case.

IV. Conclusion

We notice that the categories of damaged region to be inpainted are less when use single algorithm to inpaint the damaged Thangka image in our research of damaged Thangka image. We want to find an "all-purpose" or with generality algorithm to modify various damaged image, but the study found that it has many difficulties. Then aiming at the present condition of the filed of digital image inpainting lacking general algorithm to modify various damaged image, in order to make more types and more damaged image in different domains can be inpainted better, a new system model of image inpainting is proposed. The system model not only inpaint damaged Thangka image in different categories, but also can inpaint damaged image of different classification in other domains. Variety inpainting algorithms are integrated in the system that fit for different the damaged image. The system implementing needs to research further, with the further study, more parameters probably need to be added so that supply the better decision-making for inpainting of damaged image.

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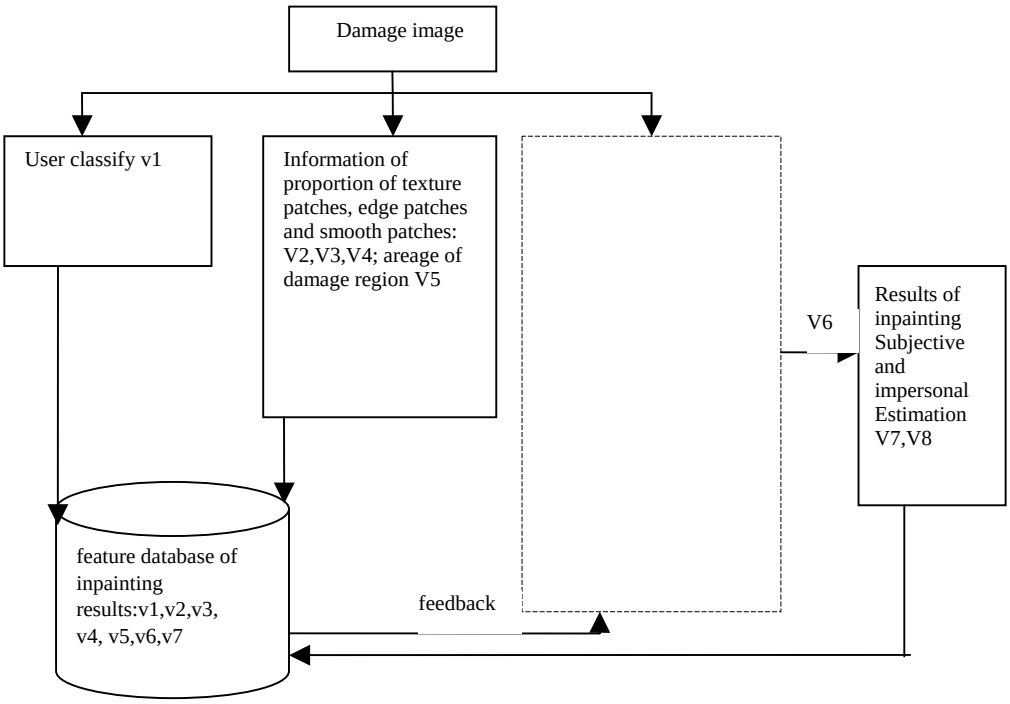

Fig 6. System model of image inpainting with subjective estimation and impersonal estimation integrated