Quality Measure Techniques for Estimating the Impact of Image Attributes on Tampering

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(Received Feb. 2015 & Published online April. 2015 issue)

Abstract An alteration or manipulation in digital images is termed as tampering. There are different techniques to detect and remove tampering from digital images. A number of attributes are associated with image and these impact the process of tampering removal. There may be dependency of different image attributes on tampering removal process. Singular Value Decomposition (SVD) is one of the robust techniques to detect the extent of tampering in digital images. SVD based Tampering Removal (SVD-TR) model which has been proposed earlier shows a significant effect of selected image attributes on tampering removal process.

Carrying out further research work in this direction, another SVD based model for quality assessment (QA) metrics (SVD-QM) has been proposed and experimentally analyzed in this research paper. This model is an extension of SVD-TR. SVD-QM model estimates the effect of selected image attributes on tampering removal (TR) process. For experimental analysis, a wide range of databases has been tested with SVD-QM model and extent of tampering removal has been calculated. Further the results obtained have been compared with Pixel Difference Mean Square Error (PDMSE) QA method. The result shows that selected image attributes impact the tampering removal process. Further, the output of SVD-QM is comparable to PDMSE QA method.

Keywords Digital Images, Singular value decomposition, tampering removal, pixel based measurement, quality assessment, SVD-TR, SVD-QM.

1 Introduction

Any intentional or unintentional modification in the contents of digital image is termed as tampering and such images are known as tampered images. Tampering may be introduced as noise, distortion, by process of copy- move, by content alteration etc. It is essential to ascertain the authenticity of such digital images. Digital image tampering detection has emerged as an important research area. There are various techniques for tampering detection like Principal Component Analysis (PCA), Discrete Cosine Transform (DCT), Discrete Wavelet Transforms (DWT) etc. Singular Value Decomposition (SVD) is one of the robust technique for tampering detection and removal. It has many applications in linear data analysis, image fusion, signal processing, pattern recognition, image compression, noise reduction, image blurring, face recognition, forensics etc. The technique involves refactoring of given digital image in three different feature based matrices. The small set called singular values preserves the useful features of the original image [2] [3]. In this research study, SVD based tampering detection and removal from digital images has been proposed. This model is an extension of SVD-TR model which has been analyzed earlier. The mathematical model of SVD-TR has been used to obtain the resultant image from the tampered images which is similar with the corresponding original image as reported earlier [6]. However, it is essential to estimate the accuracy of the resultant images. Image Quality Assessment (QA) Metrics has been used to ascertain the accuracy the resultant image [9]. The goal of QA metrics is to design algorithms that can automatically assess the quality of images in a perceptually consistent manner by comparing the resultant image with that of the original image. There are many techniques for estimating the image quality like pixel difference mean square, correlation, edge detection, neural networks, region of interest etc. Various attributes are associated with digital images like color, size, texture, brightness, format etc.

Y. Hui et al. proposed various features extracting techniques depending on the content of the image. The results were obtained using images in .jpeg format only [5]. SVD based noise removal

(DOI: dx.doi.org/14.9831/1444-8939.2015/3-4/MAGNT.13)

method called SVD-TR has been proposed by D. Sharma et al. The experimental results show a large extent of noise removal from digital images [6]. A. G. George et al. discussed about the various approaches used to evaluate the quality of an image. The Pixel Difference Mean Square Error *(*PDMSE) method is computationally not expensive but does not correlate with human perception [7]. A pre-processing method to measure image visual quality has been proposed by G. Chen et al. This approach extracts the scale invariant feature transform (SIFT) features from the reference image and the distorted image, and then finds the matching key points between the two images. The metrics includes Peak Signal Noise Removal (PSNR), Mean Structural Similarity Index Measurement (MSSIM), and Visual Information Fidelity (VIF). Experimental results show that the pre-processing method improves the metric scores considerably [9]. Y. A. Y. Najjar et al. discussed the different image quality measures like Mean Square Error (MSE), Peak Signal Noise Removal (PSNR) etc to compare the original and the distorted images [10]. B. Nebel discusses the structural features for content based image retrieval and classification problem in his research study. The image retrieval totally depends on the structure of the image i.e. size of the grid [14].

It is evident from the literature survey that there is very less research work for estimating the extent of tampering removal using SVD as well as understanding the impact of image attributes on tampering removal process. In addition, SVD based QA metric (SVD-QM) has been used for estimating the extent of tampering removal from images having different attributes. For experimental analysis, three different image attributes i.e. size, format and content have been analyzed. The results obtained from SVD-QM have been compared with one of the existing QA metric called pixel difference mean square error (PDMSE) [10]. PDMSE QA metric is computed to calculate the error *p* as in equation (1)

$$p = \frac{1}{N * M} \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} e(m,n)^2 \qquad (1)$$

where N and M are sizes of image matrix and $e(m, n)$ is the error difference between the original and the tampered images.

The proposed model shows satisfactory results with varying different attributes. In the following section, the SVD-QM model has been discussed. Methodology used to test the results and the analysis of results has been presented in Section 3 and 4 respectively. In Section 5, conclusion and the further directions of the research work are given.

2 Proposed Model

As discussed above, a novel SVD based quality assessment metric (SVD-QM) has been proposed in this study for estimating the extent of the tampering removal in digital images. SVD-QM model has been experimentally analyzed and the results obtained have been compared with PDMSE. The workflow of the proposed experimental study has been shown in Fig.1.

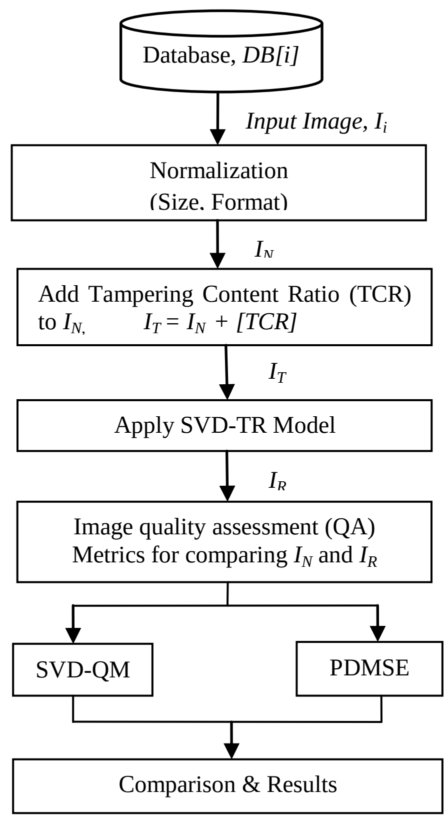

Fig.1 Proposed schematic model for estimating the impact of image attributes on tampering removal using SVD-QM

Image (I_i) from selected database *DB[i]* forms the input to the system. I_i is normalized, in specified format with respect to size and format to obtain I_N. Tampering ratio has been added to I_N in different proportions. In this study, content based tampering ratio (TCR) has been used. Then the SVD based tampering detection and removal (SVD-TR) model has been applied to the tampered image (I_T) in order to study the extent of tampering removed. The resultant image I_R has been generated. In order to compare the resultant image I_R with I_N, the proposed model SVD-QM has been used. SVD based QA metric has been applied to compare the resultant image I_R with the corresponding image I_N. The results of image comparison (*in %*) are obtained. Further, in order to check the effectiveness of the proposed SVD-QM, the results obtained have been compared with the above mentioned existing QA metric, PDMSE. The error difference between the original image and the resultant image has been calculated using equation (1).

3 Methodology

As explained above, the process of detecting and removing tampering is done with different images taken from multiple databases. To carry out the investigations, thirty images have been taken from each of three databases *DB[i]* namely - agriculture, plane-cloud database and topology database. Five images from each database have been shown in Fig.2.

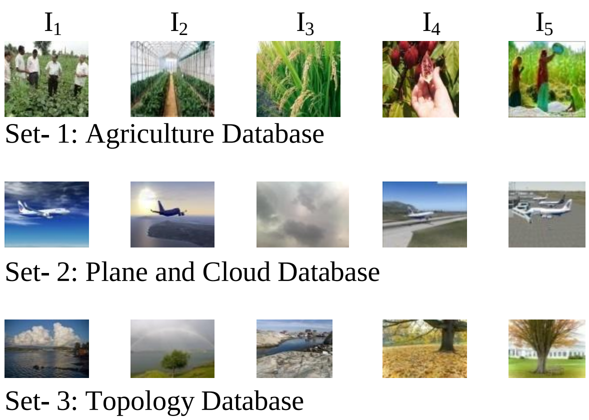

Fig.2 Three image Databases *DB* each containing five images $I_1..I_5$

Three image attributes – size, format and tampering content ratio have been selected on the basis of the literature review. These three different image database sets are processed for these selected attributes. The following image sizes are considered for further processing - $S_1 = 50 \times 50$, $S_2 = 100 \times 100$, $S_3 = 150 \times 150$, $S_4 = 300 \times 300$, $S_5 = 500 \times 500$, $S_6 = 700 \times 700$, $S_7 = 1000 \times 1000$. The image formats used for given study are .bmp, .jpeg, .png, .gif and .tiff format. The images shown in Fig.2 are accordingly converted to different formats using standard softwares. In order to carry out the SVD-TR experiments for different content ratios, the varying ratios of the contents of the one image I_i has been added to another image I_c to obtain tampered image I_T as shown in equation (2). The tampering content ratios (TCR) used in the study are 25%, 50% and 75%. For sake of the uniformity of the results, the first image of every image dataset has been kept as constant for adding tampering in rest of the images of the image dataset.

$$I_i DB[j] + I_C = I_T \quad (2)$$

where $i = 1$ *to* 6 ; $j = 1$ *to* 3

I_i is the original image which is to be generated, I_T is the tampered image and I_C is the constant image.

By using the SVD-TR model, original input image, I_i is retrieved. This SVD-TR model has been designed for the image size ranging from S_1 to S_7. This SVD-TR model shows effective results for all the images irrespective of specified size and format. The mathematical model designed for the image retrieval can be represented as shown in equation (3):

$$I = \alpha \cdot I_F + \beta \cdot I_C + \gamma \quad (3)$$

where $\alpha = 0.4$, $\beta = 0.4$ and $\gamma = 0.3714$ for gray level

α, β and γ are constants.

The values of α, β and γ has been calculated by iterative method using SVD. Using the equation (3), original image, I_i is retrieved from combined image I_F. The analysis has been done by varying two of three image attributes- size, format and TCR keeping one of the attributes constant. The attributewise results and the comparison of proposed model with PDMSE technique have been presented in the following section.

4 Analysis and results

More than 150 images taken fifty each from three image databases have been tested for three selected image attributes. Some of the results obtained from the experimental study have been presented below. The tampering has been detected and removed using the SVD-TR model. In order to authenticate the proposed model, different quality measure techniques have been used as discussed above.

The results and analysis has been presented under three sections. In section 1, the percentage extent of tampering removal on input image has been presented and analyzed for each attribute- size, format and TCR. In each case one of the attribute is kept constant. The results shown are the percentage comparison of the original image and the output resultant image obtained after the removal of induced tampering using SVD-QM. In section 2, the results of

SVD-QM are compared with the results obtained using PDMSE technique for the same set of image database and same image attributes. Finally, results of attributewise performance of SVD-QM technique are presented in Section 3.

4.1 SVD quality measure technique (SVD-QM)

To obtain extent of tampering removal for image formats, each input I_i is converted to one of the select format, tampering is introduced manually and then SVD-TR model is applied to remove the tampering. All the sizes from S_1 *to* S_7 have been tested. Different image formats at different TCR have also been tested. Some of the outputs from the experimental study have been shown in Table 1.

Table 1 Extent of TR (*in %age*) at different image sizes

Formats	S_1	S_5	S_7
.bmp	80.14	82.86	84.15
.jpeg	80.98	81.25	81.27
.gif	81.8	81.82	81.98
.png	82.25	81.84	82.63
.tiff	84.11	83.27	84.19

The output related to sizes S_1, S_5 and S_7 with different image formats of image I_2 from DB_1 are shown in Table 1. TCR was kept constant at *25%.* The results shown are in percentage.

The results obtained by computing the SVD's of image sets of different formats are shown in Table 1. The behaviour of different image formats with respect to image sizes *(*$S_1 = 50 \times 50$, $S_5 = 500 \times 500$, $S_7 = 1000 \times 1000$*)* has been compared. Some parameters of the Image I_2 from database DB_i (where $DB_j = 1$ *to* 3) is set constant so that the meaningful results are retrieved using the proposed SVD-TR model.

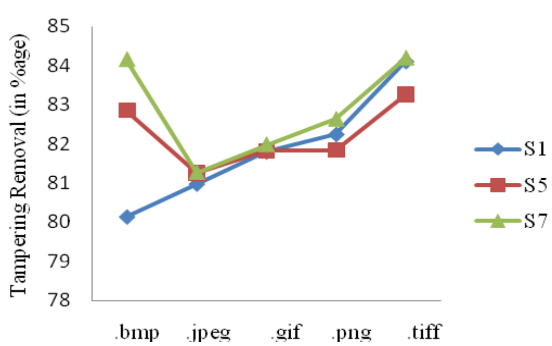

Fig.3 Extent of TR (in %age) from I_2 at different image sizes with respect to different image formats
[Image = I_2, Database = DB_1, Size = 50 x 50, Tampering Ratio = 25%]

Fig.3. The increase in image sizes results in the increase in tampering removal process as seen in above graph. The analysis shows consistent improvement in the performance of TR with respect to increase in size.

Table 2. Extent of TR (*in %age*) at different image sizes with variation in TCR

TCR	S_1	S_2	S_3	S_4	S_5	S_6	S_7
25	78.54	79.49	79.98	80.19	81.25	81.89	82.5
50	76.49	77.85	78.21	79.25	80.15	81.26	81.46
75	75.29	75.79	76.25	77.84	78.26	79.54	80.29

Different image sizes- S_1 *to* S_7 have been tested at different TCR values. In this test study, format remains constant as .bmp. This variation in results obtained by image I_2 from DB_1 using SVD-QM technique is shown in Table 2.

The behaviour of different image sizes at different TCR (*25%, 50%, 75%)* values has been compared as shown in Fig.4. Image format of the Image I_2 from database DB_1 is set constant. The results indicate that any variation in image size of the image impacts tampering removal process.

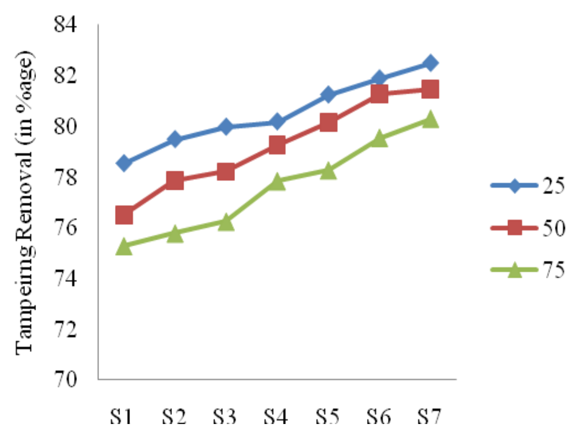

Fig.4 Extent of tampering removal from I_2 at different image sizes with respect to different tampering content ratio
[Image = I_2, Database = DB_1, Size = 50 x 50, Format= .bmp]

The results of TR (*in %age*) of image I_2 from DB_1 using SVD-QM technique are shown in Table 3. In this test study, two image attributes- fomat and TCR have been tested as size of the image remains constant at S_1. The results indicate that with the increase in induced tampering, the efficiency of TR process using the proposed model also increases.

Table 3 Extent of TR (*in %age*) in image formats with different TCR

formats	TCR at 25%	TCR at 50%	TCR at 75%
.bmp	81.25	80.15	78.26
.jpeg	68.54	68.96	68.84
.gif	77.56	76.29	77.84
.png	77.29	76.84	70.11
tiff	71.39	65.45	66.81

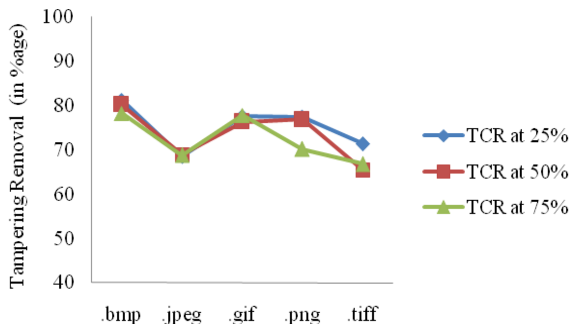

Fig.5 Extent of tampering removal from I_2 at different image formats with respect to different tampering content ratio [Image = I_2, Database = DB_1, Size = 50 x 50]

The behaviour of different image formats TR with different TCR has been shown in Fig.5 which indicates that all the formats except .jpeg show good The behaviour of different image formatsTR with different TCR has been shown in Fig.5 which indicates that all the formats except .jpeg show good result in TR with variation in TCR. The proposed SVD-QM technique shows satisfactory results in the domain of formats and TCR.

Table 4 Extent of TR (*in %age*) of different DB image sets.

image	i_2 (db_1)	i_2 (db_2)	i_2 (db_3)
TR (%)	81.86	80.45	82.97

The results of TR (*in %age*) from different databases (*DB_1*, *DB_2*, *DB_3*) using SVD-QM technique are shown in Table 4. The image I_2 from three different databases have been tested with all the three image attributes set constant- image format`- .bmp, image size - S_1 and TCR-*75%*.

The behaviour of TR process from Image I_2 of each of three different image database set using SVD-TR technique is shown in Fig.6. All the image attributes have been set constant and the results have been generated. The results obtained are shown in percentage comparison of input image with the output resultant image after the removal of tampering using the proposed model.

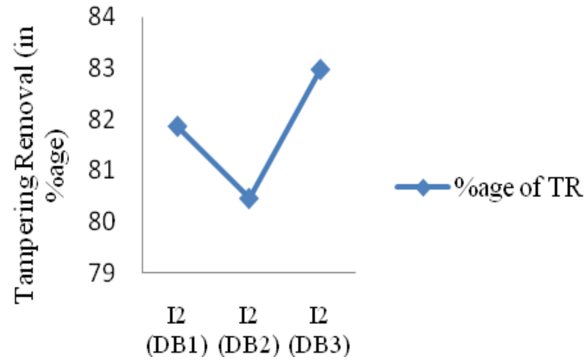

Fig.6 Extent of TR (in %age) from I_2 of three different databases
[Image = I_2, Format= .bmp, Size = 50 x 50, Tampering Ratio = 75%]

4.2 Comparison between SVD-QM and PDMSE techniques

This section presents the results of two QM techniques - SVD and PDMSE. The results obtained from these two techniques have been compared with respect to different image attributes as discussed above. This comparison investigates the extent of tampering removal (TR) and also strengthens the effect of different image attributes on tampering removal. In this experimental study, same image database sets have been used for testing and analyses.

Table 5 Comparative results of extent of TR (*in %age*) from I_2 from three different image database sets using SVD-QM and PDMSE techniques

Image	$i_2(db_1)$	$i_2(db_2)$	$i_2(db_3)$
SVD-QM	80.14	81.29	84.65
PDMSE	76.49	76.25	78.29

The comparative analysis of extent of TR (*in %age*) obtained from SVD-QM and PDMSE is shown in Table 5. In this test study, Image I_2 from three different image database sets have been used. All the image attributes have been set constant (Size-S_1, Format-.bmp and TCR-*25%)*. Both the techniques follow the same method for inducing tampering. The results obtained from both the techniques are shown in percentage. The results shows the percentage match of the input image matches with the resultant image after removing tampering using the SVD-QM and PDMSE techniques.

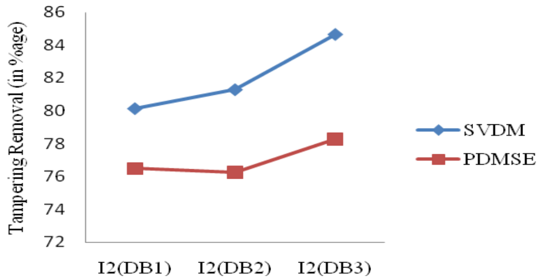

Fig.7 TR (in %age) of I_2 of three different Image databases using SVD-QM and PDMSE

[Size = S_1, Format = .bmp, TCR = 25%]

The comparative analysis of results obtained from SVD-QM and PDMSE is shown in Fig.7. The SVD-QM shows good results in TR process from I_2 from three different image databases.

Table 6 Comparsion of results for extent of TR (*in %age*) of DB_1 using SVD-QM and PDMSE technique

Iimage	I_2	I_3	I_4	I_5	I_6
SVD-QM	80.14	81.42	80.95	83.28	82.86
PDMSE	76.49	76.85	76.26	76.89	77.29

Five images from DB_1 have been tested and analysed using SVD-QM and PDMSE techniques. The results of TR (*in %age*) obtained from SVD-QM and PDMSE of different images from DB_1 are shown in Table 6. All image attributes are set constant.

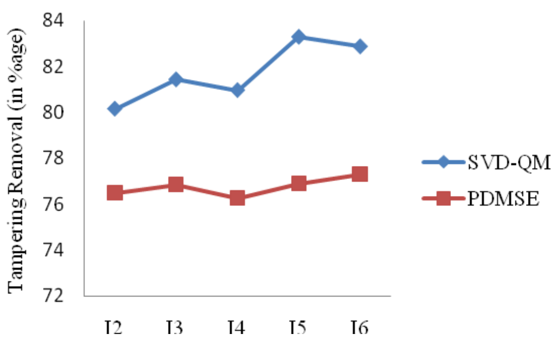

Fig.8 Comparison of extent of TR (*in %age*) from DB_1 using SVD-QM and PDMSE techniques

[Size = S_1, Format = .bmp, TCR = 25%,, Database= DB_1]

Fig.8 shows the comparative analysis of results obtained from SVD-QM and PDMSE. Different images from DB_1 have been tested and analyzed. The SVD-QM shows good results in TR process from different images from DB_1 with some image attributes remains constant.

Table 7 Comparison of extent of TR (*in %age*) from DB_1 with different image formats using different techniques

formats	.bmp	.jpeg	.gif	.png	.tiff
SVD-QM	82.86	80.25	81.82`	81.84	83.27
PDMSE	81.25	68.25	77.56	77.29	71.39

The comparative results obtained from image I_2 from DB_1 have been shown in Table 7. The behaviour of different image formats have been studied. Rest of the image attributes are set constant. The comparative results of TR are generated using SVD-QM and PDMSE of DB_1 w.r.t. different image formats.

The comparative analysis of results obtained from SVD-QM and PDMSE is shown in Fig.9. The behaviors of different image formats have been studied and analyzed with size and TCR remaining constant. The SVD-QM shows good results in TR process (I_2 from DB_1).

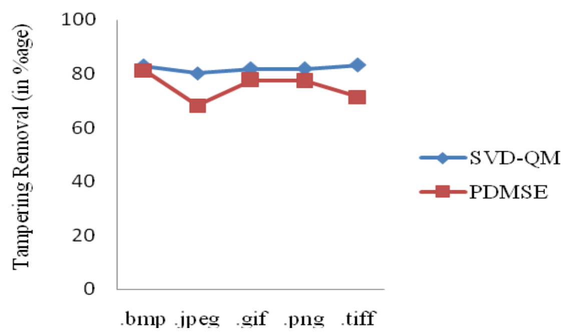

Fig.9 Comparison of extent of TR (*in %age*) of DB_1 with image formats using different technique

[Size = S_5, TCR = 25%. Image = I_2, Database= DB_1]

Table 8 Comparison of extent of TR (*in %age*) of DB_1 with different image sizes using different techniques

	S_1	S_2	S_3	S_4	S_5	S_6	S_7
SVD-QM	80.1	81.5	81.7	82.4	82.9	83.9	84.2
PDMSE	76.6	77.9	78.2	79.2	80.1	81.3	81.5

The comparative results of TR of image I_2 from database DB_1 obtained from SVD-QM and PDMSE techniques are shown in Table 8. Image sizes from S_1 to S_7 have been tested using both the techniques and results are generated. The results obtained are rounded off upto one integer decimal. Image format and TCR attribute have been set constant.

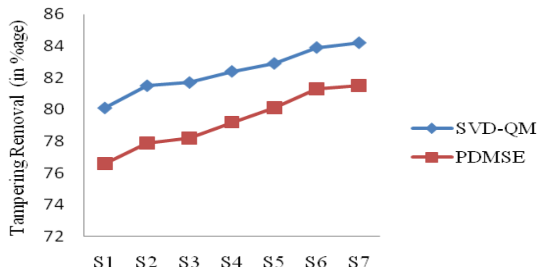

Fig.10 Comparison of extent of TR (*in %age*) of DB_1 at different image sizes using different techniques [TCR = 25%, Image = I_2, Database= DB_1, Format= .bmp]

The comparative analysis of results obtained from SVD-QM and PDMSE are shown in Fig.10. It is evident from the graph that as image size increases the computations for removing the induced tampering also increase. SVD-QM model gives better results of tampering removal across the different image sizes as compared to PDMSE.

Table 9 Comparative results of extent of TR of I_2 from DB_1 set using SVD-QM and PDMSE technique

	25%	50%	75%
SVD-QM	80.14	81.26	83.19
PDMSE	76.49	78.54	75.29

The comparative results of TR obtained from SVD-QM and PDMSE of Image I_2 of DB_1 w.r.t. to different TCR are shown in Table 9. The rest of two image attributes are set constant.

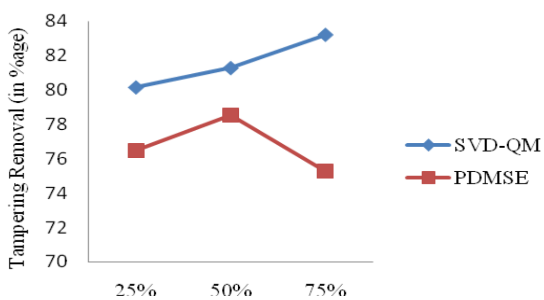

Fig.11 Comparison of extent of TR matches of Image TCR from DB_1 set using different techniques [Size= S_6, Image = I_2, Database= DB_1, Format= .bmp]

The comparative analysis of results obtained from SVD-QM and PDMSE is shown in Fig.11. The SVD-QM shows considerable good results in TR process of different images from DB_1.

From the above comparative analysis of SVD-QM and PDMSE, it is observed that SVD-QM removes the image tampering quite effectively. SVD-QM shows comparatively good results in many cases from PDMSE. The different selected image attributes have a great impact on tampering removal using SVD. It is evident from the graph that when the induced tampering is increased from 50% to 75%, SVD-QM shows persistent increase in tampering removal unlike PDMSE.

4.3 Impact of each image attributes on tampering removal using SVD-QM

In this paper, the behavior of different image attributes has been studied and analyzed using SVD based QA metric (SVD-QM). As shown in above sections, the variation in values of an attribute affects the behavior of singular vectors of SVD. The impact of selected attributes on tampering removal using SVD-QM is shown in Table 10.

Table 10 Impact of image attributes on TR using SVD-QM

image attributes	format	size	content
min	76%	79%	75%
max	84%	85%	80%
avg.	81%	82%	77%

The Min's and the Max's values of the percentages of tampering removal for respective attributes have been calculated. The corresponding average percentage of TR is also shown in the Table 10. These results show the efficiency of the proposed SVD-QM model for TR and the impact of TR from different image attributes on SVD-QM.

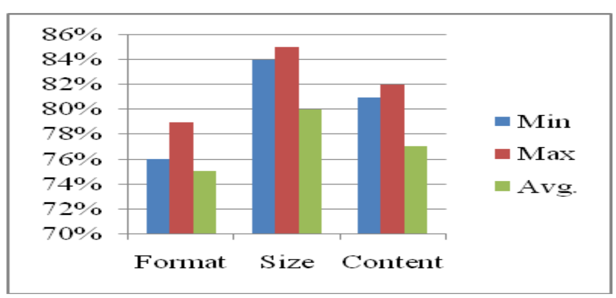

Fig.12 Impact of image attributes on tampering removal using SVD-QM

The impact of different image attributes on tampering removal using SVD-QM has been shown in Fig.12. The minimum, maximum and average values of three different attributes from the experimental study have been calculated. The graph shows persistent good tampering removal and average tampering removal is above 70%. The results indicate that there is variation in image size, as tampering removal with respect to image size shows significant impact on TR process using proposed model. The difference between minimum and maximum in case of format is maximum whereas it is similar in case of size and induced TCR.

5 Conclusion & future work

In this research paper, SVD based QM model (SVD-QM) has been proposed and analyzed. This model is an extension of SVD-TR which has been proposed earlier. SVD-QM model estimates the effect of selected image attributes on tampering removal (TR) process. In this study, a wide range of databases have been tested using more than 150 normalized images from three different databases. The extent of tampering removal has been calculated using SVD-QM. Further the results obtained have been compared by applying PDMSE method. It has been observed that SVD-QM removes the image tampering quite effectively. SVD-QM shows comparatively good results in many cases. The different selected image attributes have a great impact on tampering removal using SVD. The proposed model shows satisfactory results with varying different attributes SVD-QM and shows good results across different image attributes comparable with PDMSE.

Presently, the effect of more image attributes including the large domain of content ratios and image sizes for SVD-QM model are being experimentally analyzed.

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