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Statistical Model for the Quality of Panoramic Images of Mural Paintings

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Abstract

Panoramic image creation is crucial in area of digital imaging. It is developed by combining an overlapped image component series of a large image, which is difficult to be focused on using a normal camera due to a large field of view. Measuring the quality of panoramic images is a challenging task. Therefore, the objectives of this research are to find the attributes of visual quality of panoramic images and to propose predictor variables for a statistical model for the quality of panoramic images of mural paintings. Authors have used a proposed novel method for creating panoramic images of mural painting. In this study, authors researched on the quality attributes of digital images. Accordingly, color balance, noise and distortion were identified as the two most critical factors which affect the overall quality of the panoramic images. Authors visited three temples and captured digital images of mural paintings of large scale using a simple method. Then, panoramic images were created using three methods: the novel method with other two methods, Photoshop (available in the market) and Hugin (open source software). Subjective evaluation was applied through experts in the field of Visual Arts. Participants were asked to rate the quality using four-point Likert scale for color balance, noise and distortion as predictor variables and overall quality as the response variable of panoramic images. Ordinal logistic regression was fitted through Minitab statistical package and the results showed that color balance and noise and distortion are two important attributes for the quality of the panoramic images. Moreover, the collected data fit the model at a higher accuracy.

Keywords: quality attributes, color balance, noise and distortion, mural paintings, panoramic images

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Introduction

Mural paintings are very specific type of artifact in the domain of cultural heritage in Sri Lanka. There are various types of valuable mural paintings in the historical temples such as Bellanwila Rajamaha Viharaya, Kelaniya Rajamaha Viharaya and Sapugaskanda Rajamaha Viharaya. Some of the murals are physically large and cannot be focused at once due to a large field of view using a normal camera. It will result in quality issues such as color distortion and color unbalance. It has been identified that in the digitization process, panoramic image is a solution to capture these types of artifacts as it will allow a developer to get a series of image components with an overlapped image segments without focusing the entire image as a single entity. However, it is very important to check the level of the quality of final product to ensure the effectiveness and integrity of the digitization process. Therefore, it is very important to consider the quality aspect of the artifacts.

The general definition of image quality is the integrated perceptions of the overall degree of excellence of an image [1]. Janssen [2] defined the quality in the context of visual-cognitive systems to be the degree to which the image is both useful and natural. According to this definition, the accuracy of the internal representation of the image is called the usefulness of an image. Further, degree of correspondence between the internal representation of the image and knowledge of reality as stored in memory is called the naturalness of an image. In most of the instances, digital image quality depends on who is looking at for the image and for what purpose. Accordingly, the term image quality describes an overall visual impression as a single entity. Further, the various quality-related perceptions define several dimensions of overall image quality [1]. Therefore, it can be defined as multiple components, called image quality attributes which describe the overall perceptions such as sharpness, noisiness, and colorfulness. Therefore, the objectives of this research are to find the attributes of visual quality of panoramic images and to propose predictor variables for a statistical model for the quality of panoramic images of mural paintings.

Research Methodology

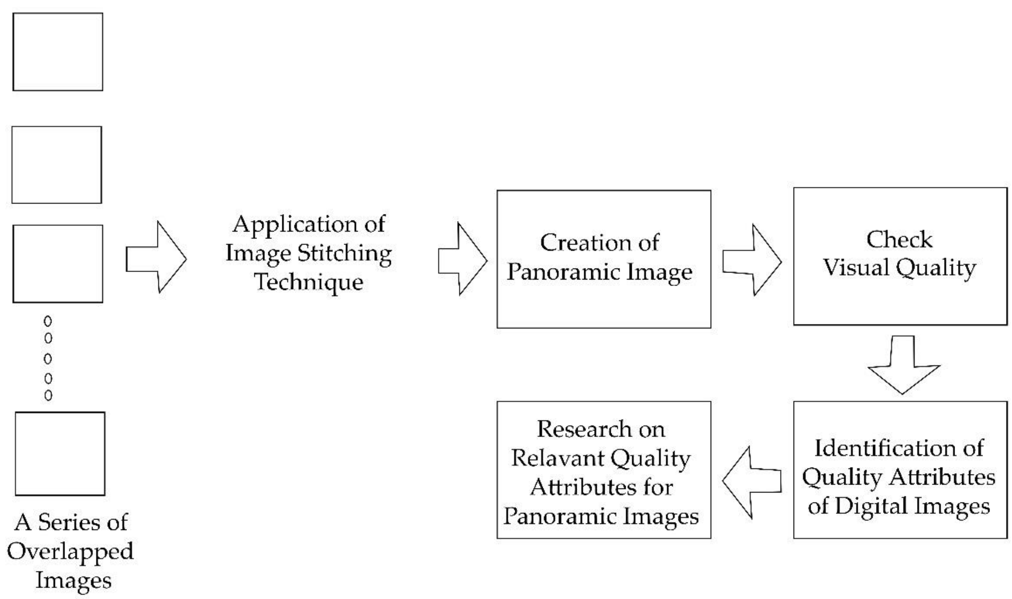

Figure 1. Steps of research on quality attributes for panoramic images

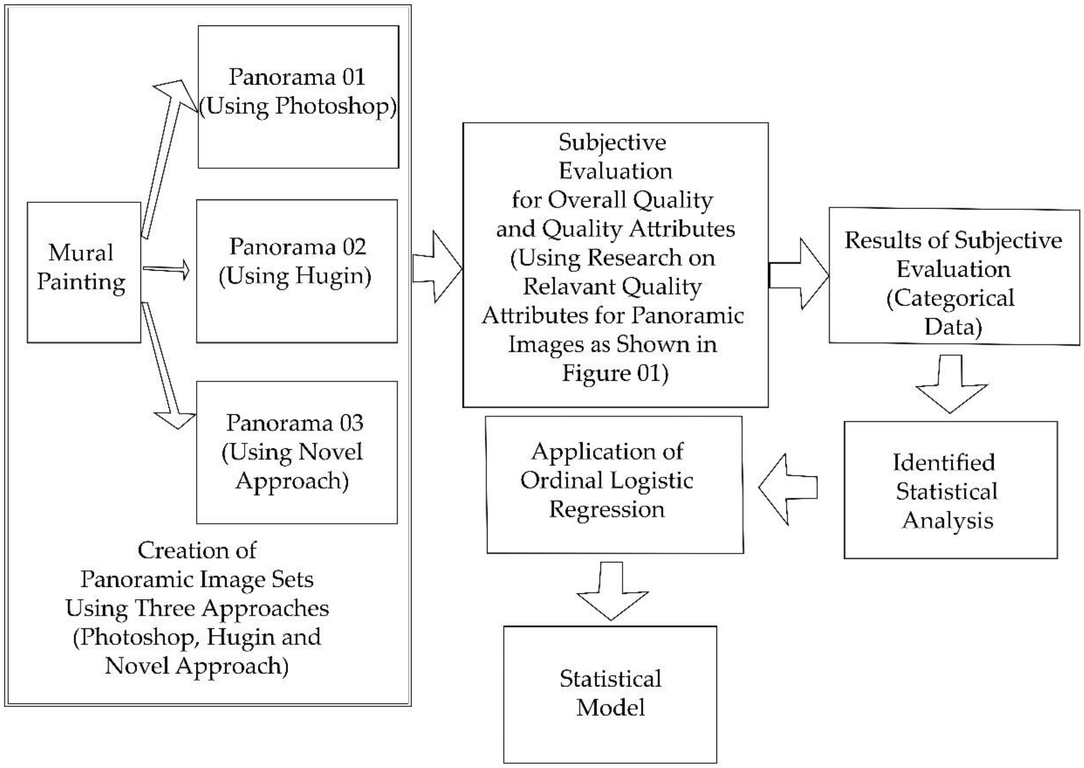

Figure 2. Identification of predictor variables for a statistical model for the quality of panoramic images of mural paintings

Figure 1 shows the application of stitching technique for a series of overlapped images and creation of some panoramic images. Authors identified that there are some quality issues of the panoramic images created by using existing methods. The quality attributes of digital images were identified by doing research. Further, the research direction was focused to identify the most relevant quality attributes of panoramic images [3, 4] and the challenges of quality assessment [5]. Figure 2 shows a series of image components of physically large murals which was captured by using a simple approach for creating panoramic images. In addition to that, it has been identified that no reference image for the panoramic image for objective evaluation. Therefore, subjective evaluation approach will be used in this context. So, a requirement has been risen to apply a quality method in the creation of panoramic images. Accordingly, it was selected an already proposed novel method which ensures the development of quality panoramic images. As a one of the major activities in the research methodology, authors tested two other software tools and observed the inconsistencies of the created panoramic images in the area of color balance and noise and distortion with respect to the authors' perspectives. Hence, it would be more justifiable and confident, if there is a possibility to get expert perceptions to justify the level of correctness of the observation and conclusion taken by the authors related to the final quality of the panoramic images. Therefore, it was planned to evaluate

the panoramic images created with two tested software: Photoshop and Hugin parallel with the evaluation of panoramic images using the new method. In this case, subjective evaluation of the created panoramic images will be done as Method A, Method B and Method C rather than directly saying their method names. This mechanism will avoid the biasness of the quality perspectives of the participants. Accordingly, 5 x 3 panoramic images were created by applying the already proposed novel method and the two software tools (5 panoramic images for each method).
After that, the quality assessment of above panoramic images was done using subjective evaluation. Consequently, a qualitative data set was obtained after the quality assessment. Then, authors opened the avenues to analyze this data set with an objective to propose predictor variables for a statistical model for the quality of panoramic images of mural paintings using a more accurate novel method.

Research on quality attributes of panoramic images

Authors researched on the quality of digital images. It was identified that there is a quality theory introduced by Engeldrum and Bartleson [6, 7 and 8]. This theory explains that the overall quality model can be established by using a most crucial set of quality attributes of an image [9, 10]. Accordingly, authors researched on the quality factors of digital images and identified the most relevant quality attributes of panoramic images by considering the nature and the theoretical background of such images [11, 12]. Specially, it was well studied the underline theory of creating panoramic images, called image stitching. Matthew and David concern the problem of fully automated panoramic image stitching and talk about two categories of literature called direct and feature based techniques. It describes an invariant feature-based approach with several advantages over previous approaches. One of the important facts of this research is the ability to match image sequence despite rotation, zoom and illumination change in the input images. Furthermore, a high-quality result is taken using multi-band blending to render seamless output panoramas. In this research, steps for creating a panoramic image are described as feature matching, image matching, Robust Homography Estimation using RANSAC, applying probabilistic model for image match verification [13]. This is a research that is presented an automated panoramic image stitching. It is different than previous approaches. The problem of fully automatic construction of panorama has been considered by the Brown and Lowe. The paper has presented a novel system for the above problem by using SIFT algorithm. That system is robust to the illumination condition, camera zoom [14]. Szeliski explains how the image stitching techniques evolved from the past up to the modern level of techniques. Techniques such as image alignment, global alignment are some of the millstones in the techniques developments which were resulted to enhance the quality of the panorama creation process. Further, it has been pointed out the main issues such as seams, blurring effect of the final output as a result of the presence of parallax, lens distortion, scene motion, and exposure differences of panoramas [15, 16]**.** Accordingly, it was identified that color balance, noise and distortion are main three factors which are highly significant in area of panoramic images [17]. Actually, noise and distortions are two factors which are tightly bound as a one factor in the context of display at the time of evaluation of the visual quality of a digital image. Therefore, these two factors were considered as a single factor at the evaluation.

Mural painting capturing and developing panoramic images of mural paintings

Authors visited three temples in Sri Lanka to shoot large mural paintings. The existing murals were captured using a good quality mobile phone camera. As it has been planned to create panoramic images for large murals, there was a requirement to get separate portions (tiles) of the same image which are overlapped. Accordingly, a series of digital image portions were taken covering all available murals in the temples and stored them separately at this capturing process. Authors created odd number of panoramic image sets (in this research 05 sets) for each software tool by using the facility available in those tools. Authors decided to select odd number of sets to avoid getting equal level percentages of preference frequencies for quality attributes at the subjective evaluation results. Accordingly, 5 x 3 panoramic images were obtained in this process.

Subjective evaluation for the quality of panoramic images

An expert group of participants was selected for the subjective evaluation as there was no reference image available for the objective evaluation [18]. In this respect, evaluated participants were selected from the field of visual arts as it was a requirement to get the individual knowledge perceptions related to the quality attributes. Accordingly, the researchers were able to find 15 experts from the faculty of visual arts for the evaluation. The panoramic image sets were demonstrated to the panel of expertise individually under three methods (software tools) separately and they were asked to rate the level of quality attributes of individual images against color balance, noise and distortion quality attributes and the overall quality. The rates selected for color balance and overall quality are Excellent (E), Good (G), Average (A) and Poor (P). The rates for the noise and distortion are No noise (N), Average (A), High (H) and Too Much (T). At the completion of the evaluation, it was able to obtain a qualitative data set under three methods.

Analysis of the data

It was researched to identify a suitable method to develop the quality model for the panoramic images. It is required to identify the association between predictor variables and responses variable for the purpose of building a model. This type of association can be measured by applying the techniques in area of statistics. Regression analysis in statistics is one of the suitable techniques to measure the association and check the level of significance of predictor variables for a response variable. Accordingly, it was identified that regression model in statistics [19] is one of the suitable models. Authors analyzed the nature and behavior of obtained data set. A categorical variable is a variable which has a measurement scale consisting of a set of categories. Any data type that can be applied as categorical variable is defined as the categorical data [20, 21]. There are two types of categorical variables depending on the type of measurement scale. Ordinal variable is one of the two types having ordered scales. Many categorical scales have a natural ordering. Some of the examples for ordinal variables are response to a medical treatment (excellent, good, fair, and poor), overall quality of a painting (excellent, good, average, and poor) and the level of a course (advanced, intermediate, basic). Categorical variables having unordered scales are called nominal variables. Examples are mode of transportation (car, bicycle, bus, lorry, and three wheel), type of music (classical, country, folk, jazz, and rock), and type of hair color (brown, black, other). Authors analyzed the obtained qualitative data set and it was identified that this data set can be defined as categorical data. Categorical data can be analyzed using statistical methods. Further, according to the statistical theory, obtained data are defined as ordinal categorical data because they are ordered and under three categories (color balance, noise and distortion and overall quality) [22, 23, and 24]. Authors, researched on a suitable regression model for this type of data and identified that ordinal logistic regression method can be applied to find the significance of the independent and dependent variables of the statistical model.

Results and Discussion

The objective of the evaluation is to find a set of predictor variables for a statistical model for the quality of panoramic images of mural paintings. Ordinal logistic regression model was applied for the regression as there are four ordered categories of data (Excellent, Good, Average and Poor). Minitab statistical package was selected for the evaluation.

Table 1. Response Information

Variable	Value	Count
Overall Quality	Excellent	16
	Good	46
	Average	12
	Poor	1
	Total	75

Table 1 shows the frequencies of responses of overall quality in the created panoramic images using the proposed method with respect to four ordered categories of data (Excellent, Good, Average and Poor) with the total number of frequencies(count).

Table 2. Logistic Regression Table

Predictor	**Coef**	**SE Coef**	**Z**	**P**	**Odds Ratio**	**95 % CI**	
						Lower	**Upper**
Const(1)	1.55373	0.705252	2.20	0.028			
Const(2)	7.78226	1.46466	5.31	0.000			
Const(3)	44.7692	6276.88	0.01	0.994			
Color balance							
Good	-2.96381	0.807985	-3.67	0.000	0.05	0.01	0.25
Average	-6.68428	1.41653	-4.72	0.000	0.00	0.00	0.02
Poor	-43.3778	6276.88	-0.01	0.994	0.00	0.00	*
Noise and Distortion							
Average	-1.80365	0.722281	-2.50	0.013	0.16	0.04	0.68
High	-19.5932	4454.98	-0.00	0.996	0.00	0.00	*

Log- likelihood = -35.545

Table 2 demonstrates the most important statistics in this regression analysis. It shows the level of significance of the categories of color balance and noise and distortion to the overall quality of the panoramic image. The P values of “Good” and “Average” categories of color balance predictor variable are 0.000 and 0.000. Since the P value of the “Good” and “Average” categories are smaller than 0.05, it can be concluded that there are statistically significant associations between the “Good” and “Average” categories of the color balance and the overall quality. The P value of the “Poor” category of the color balance predictor variable is 0.994. Accordingly, the P value of the “Poor” category is higher than 0.05. Therefore, it can be concluded that there is no statistically significant association between “Poor” category of color balance and the overall quality. The P value of the “Average” category of the noise and distortion predictor variable is 0.013. Accordingly, since the P value of the “Average” category is smaller than 0.05, it can be concluded that there is statistically significant association between the “Average” category of the noise and distortion and the overall quality. Furthermore, The P value of the “High” category of the noise and distortion predictor variable is 0.996. Accordingly, since this P value is greater than 0.05, it can be concluded that there is no statistically significant association between “High” category of noise and distortion and the overall quality.

This regression table implies that there is a statistically significant model between the predictor variables: “Good” and “Average” categories of color balance and the “Average” category of noise and distortion with the overall quality of the panoramic image.

Table 3. Test of All Slopes Equal to Zero

DF	G	P-Value
5	71.937	0.000

Further to the above results, the results of Table 3 justifies that there is a predictor variable (either color balance or noise and distortion) which affects the overall quality. Since the G value of the G test is equals to 71.937 which is a large value and P value is less than 0.05 indicates that there is a significant evidence to conclude that at least one of the estimated coefficients of the predictor variable is different from zero. This implies that there is at least one of the predictor variables: color balance or noise and distortion which affects the overall quality of the panoramic images.

Table 4. Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	8.82540	19	0.976
Deviance	9.99793	19	0.953

Table 4 shows the results of the Goodness-of-Fit Tests. It displays that both Pearson and Deviance methods of Chi-square statistics are 8.82540 and 9.99793 respectively. Further, the P values of these methods are 0.976 and 0.953. They are greater than 0.05. This reflects that there is insufficient evidence to claim that the model doesn't fit the data adequately.

Table 5. Measure of Association

Pairs	Number	Percent	Summery Measures	Value
Concordant	1316	84.7	Somers' D	0.81
Discordant	50	3.2	Goodman-Kruskal Gamma	0.93
Ties	188	12.1	Kendall's Tau-a	0.46
Total	1554	100.0		

Table 5 demonstrates the measure of association between the response variable and the predicted probabilities. This table shows that 84.7 % are concordant pairs, 3.2 % discordant pairs and 12.1 % tied pairs. These results reflect that the predictive ability of the model is good. Similarly, the statistics of the Somers' D, Goodman-Kruskal Gamma (nearly 1.0) and Kendall's Tau-a statistics indicate a better predictive ability of the model. This implies that there is a good measure of association between response variable and the predicted probabilities.

The results of the tables 3, 4 and 5 further justify that proposed predictor variables: color balance and noise and distortion for a statistical model for the quality of panoramic images of mural paintings in table 2 fit at a higher accuracy. This accuracy can be further justified by analyzing the following logistic regression tables (Table 6 and Table 7) related to other two software tools: Photoshop and Hugin.

Table 6. Photoshop: Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95 % CI Lower	95 % CI Upper
Const(1)	-2.10231	1.42105	-1.48	0.139			
Const(2)	2.10230	1.42105	1.48	0.139			
Color balance							
Good	1.72536	1.51106	1.14	0.254	5.61	0.29	108.53
Average	-0.188025	1.45311	-0.13	0.897	0.83	0.05	14.30
Poor	-2.08513	1.56892	-1.33	0.184	0.12	0.01	2.69
Noise and Distortion							
High	-0.975611	0.731260	-1.33	0.182	0.38	0.09	1.58
Too Much	-1.44111	0.656656	-2.19	0.028	0.24	0.07	0.86

Log-Likelihood = -52.615

Table 7. Hugin: Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95 % CI Lower	95 % CI Upper
Const(1)	-25.5821	26863.0	-0.00	0.999			
Const(2)	-21.3436	26863.0	-0.00	0.999			
Color balance							
Good	23.0328	26863.0	0.00	0.999	1.00696E+10	0.00	*
Average	20.7671	26863.0	0.00	0.999	1.04486E+09	0.00	*
Poor	18.9467	26863.0	0.00	0.999	1.69215E+08	0.00	*
Noise and Distortion							
Average	1.92115	2.09863	0.92	0.360	6.83	0.11	417.54
High	-0.0533333	2.10786	-0.03	0.980	0.95	0.02	59.03
Too Much	-1.81660	2.17684	-0.83	0.404	0.16	0.00	11.59

Log-Likelihood = -33.404

These tables show the level of significance of the categories of color balance and noise and distortion to the overall quality of the panoramic image. In Table 6, the P values of "Good", "Average" and "Poor "categories of color balance predictor variable are 0.254 0.897 and 0. 184. Further, P values of "High" and "Too Much" categories of noise and distortion variable are 0.182 and 0. 028. It can be concluded that there are no statistically significant associations between any of the categories of the color balance or noise and distortion and the overall quality, since all the P values except one category (*for Too Much noise and distortion*) are higher than 0.05. In table 7, the P values of "Good", "Average" and "Poor "categories of color balance predictor variable are 0.999, 0.999 and 0.999. Further, P values of "Average", "High" and "Too Much" categories of noise and distortion variable are 0.360, 0.980 and 0.404. Since all the P values are higher than 0.05, it can be concluded that there are no statistically significant associations between any of the categories of the color balance or noise and distortion and the overall quality. Accordingly, when we compare the three logistic regression tables related to new software and other two software tools, it will further justify that only the logistic regression table which was obtained through novel method confirms that the proposed predictor variables: color balance and noise and distortion for a statistical model for the quality of panoramic images of mural paintings in Table 2 fit at a higher accuracy.

Conclusion

Authors can give a clear justification of confirming initial two objectives: finding the attributes of visual quality of panoramic images and to propose predictor variables for a statistical model for the quality of panoramic images of mural paintings. In this research, the selected mural paintings were in different shapes in terms of mural painting types and the complexity of the contents. Some of them were situated in the ceilings of the temple and other were on the walls of the temple. The orientations were also different as some of them are vertical shapes and some of them are horizontal shapes. There were some murals which depict several objects and some with an individual object. Accordingly, one implication of this research is that the conclusion is valid for any type of mural paintings. Further, there is another implication regarding the image capturing process. A deeper concern should be given regarding the required amount of overlapping between two consecutive image components and to keep the parallelism between the camera and the object to ensure a minimum noise and distortion and the maximum level of color balance. As a future enhancement, this research can be done for 3D artifacts and observe whether there are different set of quality attributes and predictor variables in 3D context. Moreover, the authors are planning to apply this research for several 2D artifacts in other traditional temples in Sri Lanka and observe the results of subjective evaluation as a future enhancement of this study. Finally, it is evident that the research discloses two objectives: finding the attributes of visual quality of panoramic images and proposing predictor variables for a statistical model for the quality of panoramic images of mural paintings have been successfully achieved.

Conflicts of Interest

The authors declare no conflicts of interest.

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