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A Novel Method for Emotion Extraction From Paintings Based on Luscher's Psychological Color Test: Case Study Iranian-Islamic Paintings

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ABSTRACT Paintings evoke certain emotions in the viewers. Colors, shape, texture, and many other factors affect the feeling conveyed by paintings, but colors seem to have a stronger effect due to a century-long study of color-emotion association in various fields of psychology, art, and color science. There are many color-emotion theories and most of them have been implemented, however, the Luscher Color Test is untouched amongst them. Based on several reasons, discussed in detail inside the paper, we believe this theory can cover problems in this domain of emotion extraction. The main motivation for choosing the Luscher test was that this method is designed for personality and mood analysis and it can better study abstract paintings. In this paper, a set of paintings from Iranian-Islamic cultural heritage is chosen as a dataset. We have proposed the L-EEP method based on Culture Technology (CT) concept to extract emotions from paintings with image processing techniques and psychology knowledge. This method extracts specific colors from paintings and by performing the Luscher test automatically, is able to determine eight emotions. For this matter, paintings are assessed in two moods: 1. The full extent of the painting 2. Cropped interest area of the painting that attracts more attention. Then, the color palette which is extracted colors ordered based on their coverage extent enters search engine. The search engine performs the searching process in the 3D knowledge base of Luscher color-emotion layers to extract relative values of emotions in both scenarios. For the evaluation of the results, three steps were taken. First, we compared the output results of ancient Persian painting with literature and text of their background stories. Then a viewer evaluation is done to compare the results with human viewpoint. Finally, a set of modern abstract paintings peer-rated in the IAPS standard system to further examine the proposed method. The results of the three forms of evaluation indicate the applicability of the L-EEP approach.

INDEX TERMS Color, culture technology (CT), emotion, L-EEP, luscher color test, painting.

I. INTRODUCTION

When people look at paintings, they feel certain emotions. On the other hand, paintings are actually painted to convey a message or just to visualize the painter's inner feeling. In fact, in some painting styles, like Expressionism, the artist tries to depict a special emotion. But what makes a painting possess a certain emotion?

Although previous works have proposed some factors such as color, composition, texture, and content [16], this still is an active research field. However, due to a century-long study by specialists in diverse fields such as psychology, color science, and art, there is a great relationship between colors and evoked emotion in human and it has a universal trend [9].

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Therefore in this study, we focus on the colors that shape the paintings.

Here is another question. Why is it important to study paintings? Painting styles are different among different cultures. Paintings are part of a country or nation's artistic and cultural heritage, depicting the identity and history of those people. It is important to keep cultural diversity in the world as stated by UNESCO. With the advent of new technologies, it is possible to better preserve and understand cultural content. This idea was first developed by Professor Kwangyun Wohn as Culture Technology (CT) in 1994. Its goal was to take advantage of technology to better study, analyze, and disseminate culture. In Culture Technology, every possible cultural phenomenon such as literature, dance, painting, film, etc. is studied. Here we are focused on paintings and to better understand the emotion that they evoke through technology. Persian culture has had a strong influence from early ages and its myths, poems, and stories have spread its culture in a wide range.

In this paper, we are going to study ancient Persian paintings as cultural content and present a metric for the extraction of emotions evoked by abstract paintings through their colors. There are several methods to study the relationship between colors and emotions which will be discussed in detail in the literature review. In abstract paintings, color choice is affected by the personality and thinking of the artists. For the color-emotion part, we are going to use the Luscher Color Test, which has not been used in the domain of emotion extraction from paintings or images and also this method is designed for personality and mood analysis [35], [36]. Furthermore, we will have three types of evaluation for various purposes. Once we will compare the results with literature texts of the background stories of the paintings. Then a user study is done for better evaluation of the L-EEP method. Finally, a peer-rated data set of modern abstract painting in the IAPS format from [16] is used to further examine the applicability of the method.

The remainder of the paper is as follows: in section 2 a broad study carried out in this multidisciplinary field is presented, then the untouched psychological theory Luscher color test, the overall process of the proposed method and finally every step of the process is discussed in detail in section 3. The dataset used and the results of the implementation of the method and the evaluation are expressed in section 4. In the end, section 5 discusses the conclusion and final remarks.

II. LITERATURE REVIEW

A. CULTURE TECHNOLOGY

Culture technology (CT) is a new and emerging paradigm that has the purpose of using cutting edge technologies to explore and disseminate the best of cultural resources. Culture technology will come in all areas where there are cultural content and will try to help better illustrate and further understand it. This new tool is used in the fields of visual technology, interactive technologies, music and sound technology, computing design, cultural complexity, and cultural heritage. Paintings are one part of the ancient visual heritage of human beings. Therefore, paintings can be considered as a cultural resource and furthermore, in different cultures, the style of painting is different, and historical paintings compose part of the culture of their country. In the field of culture technology, the science of color and art is also important, and research has been carried out in this field as well, [18]–[20], [26]–[29].

B. COLORS AND EMOTIONS RELATIONSHIP

There is more than a century of study on the effect of color stimuli on evoking emotions. An extensive study on researches done in various fields such as commerce, nutrition, psychology and biology in [1], shows that color influences human perception, behavior, and feelings. In all studies, there is no significant difference between the opinions of men and women in their feelings about colors, and it has also been concluded that people from different cultures display a nearly similar attitude to the emotions evoked by the colors [9]. The first scientific study to find the relationship between color and emotion is [2]. In this research, a predefined list of adjectives and eight colors were used for polling, and some colors were associated with certain emotions. In [3] relationships between three properties of color, hue, brightness and saturation and emotions were studied. In [4] no predefined list of adjectives was used. Instead, people have been asked how they feel towards colors and why they feel so, and these emotions were put in three positive, negative and neutral categories. The results of this research showed that some of the colors like red, blue, and black have both positive and negative meanings. In [5] and [6], the effect of single-color and two-color combinations were investigated. Also, a three-dimensional space with the dimensions, color activity, weight, and heat, was designed for both single colors and two color combinations. In [7] an idea is proposed in which three scales of pleasure, arousal, and dominance are used. This system (PAD) is a general framework for the expression of adjectives and its validity has been proved in previous studies. In this system, only single colors based on the Munsell color system were used, and the relationships between the three scales and brightness and saturation of colors were found, but it failed to provide a clear relation to the color hue. In [8], a three-dimensional coordinate system for single color and three color combinations was created. But this failed to display all the compounds on the coordinate grid, and there are also no precise coordinates for the shown compounds, and the extracted attributes are only displayed in two dimensions.

In this study, the Luscher Color Test [10] will be used to extract the emotions of the colors. Our motivation for this choice has several reasons: first, not only single colors but also color combinations are important in this test. In many studies, it has only been said which color is related to what emotion, and sometimes the colors have both positive meanings and negative meanings. For example, in [4] for red, positive attributes such as love and negative attributes such

as evil are associated, but which one should we consider? Furthermore, in the Luscher Color test, single colors and their combinations do not have a consistent meaning and their selection priority affects the type of feelings. Section 3-1 discusses the Luscher Color Test in detail.

C. PAINTINGS AND EMOTIONS RELATIONSHIP

Over the past few decades, many studies have been done to create recovery and retrieval systems based on content (CBIR) and emotion semantics (ESIR) inside images [11]. One of the ways to achieve this kind of system is to extract emotions in the images. Many studies [12]–[16] have been done in the field of extracting emotions based on a variety of features such as color, texture, composition, content, etc., or a combination of several features. One of the first attempts in creating a system for searching images based on semantic queries is [12]. In [13], a method for classifying the paintings based on their style has been proposed with suitable accuracy. In this study, the HSV space is used because of its closeness to human eyesight, and several appropriate features for this work are applied in the grayscale and color images of the paintings. However, in both of these studies, emotions have not been taken into consideration.

In [17], first a color segmentation was applied to the images and then a meaningful description of colors was created by a fuzzy algorithm. But in the end, to search for images by emotional words, empirical rules were written, which did not have a particular scientific basis. The purpose in [15] is to develop a system, based on machine learning that can identify the emotions in paintings. For this purpose, an SVM classifier has been used for learning emotion categories with the help of Wiccet and Gabor features. The standard image data set of IAPS has been used as a test and train data. In [16], IAPS images were used, but due to the use of photographic laws such as depth of field and level of detail, their results were more accurate than those of [15]. However, these types of research have worked on the feelings of the images, while our goal is to study paintings. Color space is different in pictures and paintings [22]. The content of the images is real objects that have their natural color, but in the abstract paintings, the painter, based on their personality and the emotion they want to convey to the viewer, decides which color to use.

In [21], a system for categorizing paintings as positive, negative or neutral based on LAB color space and SIFT descriptor was proposed, and they used abstract paintings of MART that were surveyed on a Likert scale of 1-7. In [14] data of [21] was used, and it aimed to find the relationship between colors and emotions using a fuzzy color histogram. In [18], the goal is to create a recommender system that offers the closest sensory music to painting and vice versa. In this work, the Kobayashi's Color Image Scale [8] has been used to extract emotions of paintings. Then the extracted emotions were transferred to the arousal and valence space in [23] so that each painting has a specific coordinate and can be linked to the closest music based on Euclidean distance. Kang et al. [19] attempt to find the exact coordinates of all three color combinations in the Kobayashi's Color Image Scale, this is due to the lack of this information in Kobayashi's work. But in the end, they did not achieve good precision. They developed their work and in [20] with better strategies for choosing three color combinations, and also comparing the results of emotion extraction with a survey on Amazon MT, they came up with good results.

A very interesting and notable point is that, in the reviewed works above, a single emotion was associated with an image or painting, while each painting or image can depict several emotions. The reason for this problem is the use of classification and its nature of classifying each object in a class. Our L-EEP method based on the Luscher test can assign multiple emotions for a single painting. Also, the Luscher Color Test has not been used in this domain. However, this is a very efficient test yet designed simply, and it is very suitable for analyzing abstract works since it is designed for personality and mood analysis. This test has been used in other areas [24], [25] and has shown its effectiveness. In this paper, we intend to study Iranian-Islamic authentic paintings and more specifically extract their emotions with the help of an expert system based on image processing and psychology knowledge.

III. METHODOLOGY

A. LUSCHER COLOR TEST

The Luscher Color Test is a simple yet powerful test to understand the personality of a human. In this test, eight colors are used that consist of four basic colors (blue, green, red, and yellow) and four auxiliary colors (purple, brown, gray, and black) and the subject's color preference in choosing the colors is important in revealing their characteristics. The Luscher Color Test is devised by Dr. Max Luscher in Basel, Switzerland. Although this is designed simply, it is a powerful tool for personality assessment. In the ordinary form of the test, a subject puts the eight color cards in order of their preference. The basic colors represent good personality features, while the auxiliary colors demonstrate less good personality features. In this test, each color has special meanings, but we have extracted eight main emotions for eight colors that are presented in Table 1.

TABLE 1. Emotions related to each color in Luscher color test.

Color		Emotion
Gray	→	Inattention
Blue	→	Calmness
Green	→	Persistence
Red	→	Passion
Yellow	→	Wish
Purple	→	InteractiveRelation
Brown	→	Physical Pain
Black	→	Despair

These emotions are not just words, but they have a wide meaning, and they were selected in a way to represent their

TABLE 2. Emotions and their relative meanings.

Emotion	Relative meanings
Inattention	• In contrast to attention and importance. • The heedless person is not affected by things and wants to get away from the problems and make way for escape. • Some things do not matter to them.
Calmness	• In opposition to anxiety and emotional pressure. • A person who is calm is doing his activities purposefully. • They do not lose their temper immediately and patiently solve their problems. • They do not suffer from stress and do not feel disturbed and have no anxiety.
Persistence	• This element consists of a negative and positive aspect. • Positive aspect: insistence and pride and religious persistence • Negative aspect: pride in front of others, selfishness, and etc. • Generally, a person who does not give up on his standards in any terms.
Passion	• In contrast to the lethargy. • Most enthusiasm for a romantic aspect, without tact, without thinking. • A passionate person is very inclined to do something and has a high demand from emotional relationships. • Acts suddenly on the verge of madness
Wish	• There is no reluctance to do something. • Wish is purposeful. • It can be both in the direction of evil or good.
Interactive Relation	• In contrast to isolation and bad morality in the relationships with others. Has a positive relationship. • There is a sense of cohabitation. • Likes to consult and be in friendly environments.
Physical Pain	• Severe anxiety that can lead to physical discomfort. • The pain that affects life. • Disturbed senses - a possibility of seizure or heart attack
Despair	• In contrast to having hope and desire for the future. • The person surrenders and escapes from solving problems. • Gives up soon. • Has no goal to deal with problems. • They want nobody to interfere with them and tend to be alone.

meaning and their color the most. In Table 2, emotions and their meanings are presented.

Also, Dr. Luscher created five blocks and each block is for two colors. The first two colors are related to the first block, and they are the colors that the subject likes the most. The third and fourth colors are related to the second block in the Luscher test which reflects the current state of the subject. The fifth and sixth colors are related to the third block. This block shows the characteristics that the subject has put aside temporarily and may be used at the right time. The fourth block is related to the last two colors which are hated the most by the user. Dr. Luscher also created a fifth block which includes the first and last colors. These blocks each have eight 2D layers for the emotions stated above and they contain 56 elements (all possible two color combinations), so the order of the two colors in each layer is also important. Each element contains statements about the subject selecting those two colors, to use these blocks, we have created five 3-dimensional matrices, the row, and column dimensions consist of eight colors, and the third dimension has the eight emotions stated above. Elements of these matrices were rated based on eight emotions by experienced psychologists to form our knowledge base.

B. OVERALL PROCESS

The overall process of the proposed novel method based on the Luscher Color Test for emotion extraction from paintings (L-EEP) is described here (Figure 1). For extracting emotions of paintings, we need a sorted color palette as an input for the Luscher test. Our idea is to sort the colors based on their usage frequency in the paintings since the prominent colors attract human attention the most, thus having more impact on the emotion felt by the viewer. However, this idea is not always true. The color of the background of paintings is a great deal but have less impact on the evoked emotion so this could affect the color palette and more importantly the result of the test. Therefore, we have considered two cases:

- The raw image of the painting (right side of the flow chart)
- The cropped image of the painting (left side of the flow chart)

In the process flow of case 1, first, the color space of the image is converted from RGB to HSV. This is due to the color perception of human beings and their difference with the computer graphics notion. The eight colors mentioned in the previous part are detected with thresholding in HSV space, and the pixels relating to each color are counted, then by sorting the colors from most used to least used, we can

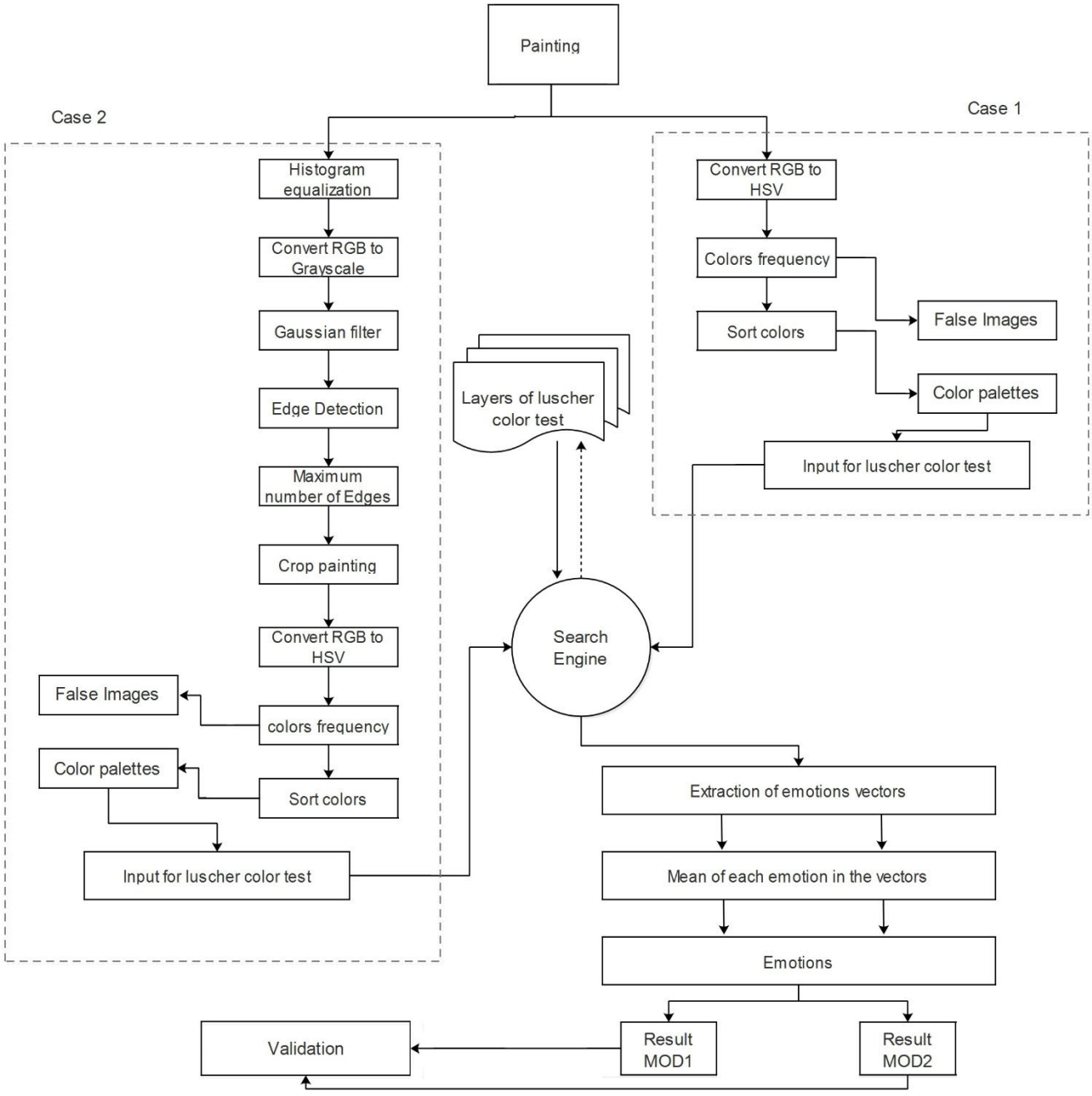


FIGURE 1. **Overall process of the proposed method.**

achieve the color palette. The false image is the image with the same size of the original image but with the detected pixels and their colors which is useful in evaluating the color detection process. In the end, the Luscher test is done with the input color palette and the emotion vector is calculated as the output emotion of the painting.

In case 2 instead of the original image of the painting, the cropped image goes through the same process discussed in case 1. For cropping the interest area from the painting, a set of processes are considered. First, it is necessary to do histogram equalization for achieving better results. Then the color image is converted to grayscale. For removing the noises in the image that occurred during the time, the Gaussian filter is applied. Then the image is ready for applying edge detection features that helps us to crop the interest area from the painting. Finally, the cropped image goes through the same process in case 1 and its color palette is extracted and then the Luscher test is done for the second time on the painting with the new color palette.

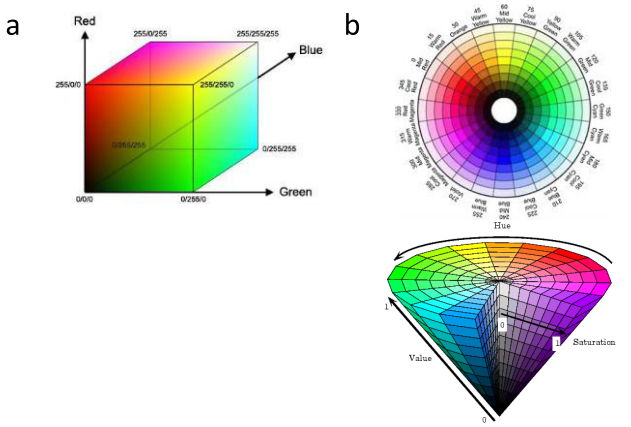


FIGURE 2. (a) RGB; (b) HSV color space.

The five blocks with eight layers in Dr. Luscher's test, described in section 3.1, were rated by specialists and psychologist and based on that we created a 3D knowledge base. When a color palette enters this knowledge base five emotion vectors are extracted by each block. In our previous study [30], we naively calculated the mean of these blocks, but here we will study the results of each block besides the mean of the vectors to have a better understanding of the Luscher test. In the following parts we will discuss each step in detail.

C. COLOR SPACE

The human perception of color is determined by the nature of the light. Visible colored light contains electromagnetic spectrum colors ranging from 400 to 700 nm. This definition has a physical aspect and is not correspondent to the system of human vision and perception. In RGB space, the color properties are semi-intuitive and dependent on measuring instruments. In RGB theory based on three red, blue and green colors, a Cartesian coordinate system is used to express the color space, with the black color at the origin of the coordinate system and the white color at the corner of the cube with the maximum distance to the origin.

The phenomenon of color recognition in humans is a physiological phenomenon. The sensitivity of the human eye system to brightness changes is due to the hue and saturation. Hence, the most similar to the human eye are HSL, HSV, and HSI color spaces. Also, the space should have the ability to be easily discrete for color separation thus reaching color recognition.

In the HSV space, hue represents the pure color based on the degree in the circle. Saturation indicates how intense the color is. Value, also represents the brightness. On the other hand, the HSV is suitable for segmenting noisy color images.

As a result, we use HSV space for two reasons: firstly, because HSV color space compared to other color spaces, such as RGB, is much close to how human beings conceive color. For example, in RGB three colors are considered independent from each other and all other colors are combinations of these three red, green, and blue colors which are used in computer vision but in HSV colors are not considered independent from each other and three attributes (hue, saturation, value) of colors are considered to form different colors which is close to nature of human vision and how they perceive colors [37]. The other is the convenient color separation that can be used to distinguish and measure color abundance.

D. COLOR FREQUENCY

In order to achieve color palette, we need to calculate frequency by counting the pixels containing of the eight colors detected in HSV space and sort them in a descending order. After obtaining the color palette, each two colors go into their relative blocks, respectively and there is also a fifth block comprised of the first and last color in the Luscher test.

To display the performance of color recognition, we made a false image by assigning the pure color of each of the octagonal colors to the detected area. In this way, we created an image, combining the eight Luscher colors. For example, part of the main image of homay and homayoon, its relative false image and its color palette are depicted in Figure 3 to 5.

FIGURE 3. Main image.

FIGURE 4. False image.

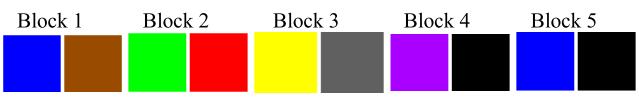


FIGURE 5. Color palette and relative blocks.

E. INTEREST AREA DETECTION USING IMAGE PROCESSING

The image processing at the beginning of case 2 is discussed here. As mentioned in section 3.2, a histogram equalization is

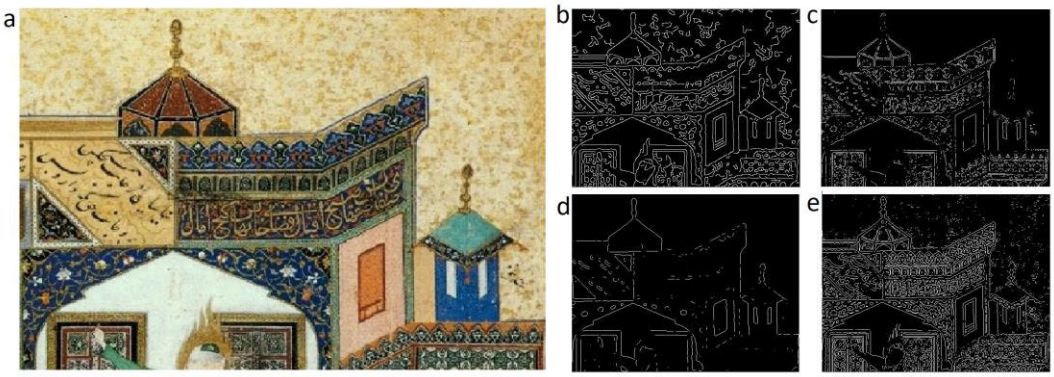


FIGURE 6. (a) main image; (b) canny; (c) sobel; (d) prewitt; (e) zero cross edge detectors performance.

applied to the color image of the painting. This is an important part of the processing of digital images, and it is used to find better and more accurate edges.

To find the edges, we convert the image to a gray image by the following relationship:

$$\text{Gray scale} = 0.2989 * R + 0.5870 * G + 0.1140 * B \quad (1)$$

Then, we apply the Gaussian filter with sigma 2 in order to smooth the image. The resulting smooth image is ready for edge extraction. Various algorithms are available for this purpose, among which Prewitt is suitable for paintings (due to unwanted noise in their images).

The way to find the edge using the Perwitt operator is by applying the following windows in line with rows and columns:

TABLE 3. Perwitt operator windows and formulas.

Gy	Gx	Edge detection formulas
+1 +1 +1 0 0 0 -1 -1 -1	-1 0 +1 -1 0 +1 -1 0 +1	Edge magnitude = $\sqrt{G_x{}^2 + G_y{}^2}$ Edge direction = $\tan^{-1}\left[\frac{G_x}{G_y}\right]$

Now, in the resulting image, we consider the part of it where the most dispersion of the edges in the image appears. The purpose of this work is to find the eye catching part of the painting and also to omit the background color which has a great deal of abundance and less impact on the viewer and the emotion that the picture convoys. So the detected area is cropped from the original image and enters the process as an input then the Luscher test is applied to the new image.

F. EMOTION EXTRACTION

As discussed before, the Luscher color test has 5 blocks with 56 color (diagonal is impossible) combination possibilities and we have extracted 8 main emotions with the help of psychologists so each block has 8 layers. Therefore, a block is a square cube of size 8. After determination of color palette, a vector with the size of 1∗1∗8 is extracted from each block consisting of eight emotions.

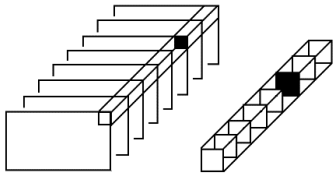


FIGURE 7. Schematic emotion vector extraction from a block.

At the end we will have 5 such vectors. In our previous work [30], we only considered mean of the vectors as the result of paintings emotion, but here we are going to study all the vectors besides mean vector and also we will have two cases for each painting.

IV. RESULTS AND EVALUATION

In this part, the paintings used and the results of the method will be presented. For the evaluation, we have taken a three-step approach in which first a relative evaluation of the results based on the literature and texts related to the ancient Persian paintings is done. Then, a viewer evaluation is carried out by a survey and comparing it to the output results of the method. Finally, for further evaluation of the method, a modern data set of abstract paintings which is peer rated in the IAPS standard system is chosen and the results are compared with a successful previous work.

A. PAINTINGS

For the experiment purpose and evaluation of the L-EEP method, we need a ground truth dataset of paintings. Except for IAPS, which is a dataset of pictures, there is no special painting dataset. Furthermore, the results of any other work are different from the results of the L-EEP method because the Luscher Color Test is not used in this domain, and it has a different set of emotions. In our previous work [30], we used the 16 paintings in Kobayashi's work, and we had to have a set of rules to convert resulting emotion vectors to the color image scale of Kobayashi which could normally cause

some errors in the mapping process. In this work, we will use 8 paintings from Iran's cultural heritage (Table 4) as our purpose is studying our cultural heritage with the concept of Culture Technology (CT). These paintings are masterpieces of the Iranian painting style called Miniature [31], [32], they are also illustrations of great Iranian myths and poems such as the Book of Kings (Shahnamah), Bustan, and etc. This could be used as an evaluation of the results, other famous paintings do not have certain emotion tags, and there are various viewpoints about what they mean and what emotions they evoke, so it would be rather difficult to validate the results with those kinds of data sets. Our dataset may seem small that is because we do not have the intention of classification.

B. RESULTS AND RELATIVE EVALUATION

The eight paintings mentioned went through the process, and the results of each block and mean result of them for every emotion is depicted in Table 5. Four of the paintings (1, 2, 5, and 6) when they went through the case 2 did not have any change in their color palette so the results for them did not change and remained as case 1. In painting 1 ''The falling of Rustam'', the last scene of the Book of Kings or Shanamah, is illustrated in which the hero Rustam and his horse, Rakhsh are killed by Rustam's brother, Shaghad and also Rustam takes his revenge before falling into the well full of spears. So the painting is a combination of sadness and pain [31]. In the results for painting 1, we can see despair has a relatively high value and calmness is low. Physical pain is medium which we expected to be high.

In painting 2 ''Prince Humay at the palace gates of Princess Humayun,'' a love scene between a prince and princess is depicted based on a poem, and there are also elements of love in the painting such as the birds flying and spinning above the tree [31]. As expected the values of emotions, wish and passion is high. Also, the emotions despair and physical pain are low, and calmness is above medium.

Painting 3 ''Shaikh Mahneh and the Villager'' is from Mantiq al-tair or Language of the Birds book and is related to a story by the name of talab or quest. Briefly, Shaikh Mahneh (Abu Sa'id Mihna'i, 967–1049), a famous shaikh of Khorasan, wandered in the wilderness in a state of depression. He saw a peasant in the distance cultivating a wasteland with an ox-plow with light emanating from him. Shaikh Mahneh approached the peasant and told him of his painful condition. The peasant advised him to be patient and pursue the endless quest. In the results, despair and physical pain should be high but they are in the medium level while wish and interactive relation scored high and calmness is low as expected.

Painting 4 ''The Seduction of Yusuf'' is based on a story in the holy Quran about Yusuf or Joseph, the prophet in Egypt that fled from Zulaikha, Potiphar's wife, who wanted to seduce him. So the high values for the wish, passion, and interactive relation is acceptable. Persistence should be high but in the result of case 1, it is low. However, in case 2, it is improved to a relatively high value.

Painting 5 ''Kay Khosrow slay Shideh'' is based on a story in Shahnameh or Book of Kings that Kay Khosrow wants to take his father's revenge, and he kills Shideh [33]. Persistence and passion have high results but calmness is low. That is in line with the story, but physical pain and wish have a medium value which we expected to score higher.

Painting 6 ''Saadi and the Youth of Kashgar'' is based on a story in Saadi's Golestan or Rose Garden in which Saadi on his journey meets a young boy in a school of a mosque learning Islamic practices, and the boy asks about his birthplace. By the answer of Shiraz, he asks the old man about Saadi the great poet of Shiraz. Later he discovers that the old man was Saadi himself and asks him to stay more, but he refuses gives the young man some advice [34]. In the results, interactive relation, wish, and calmness are high and physical pain and despair are low which are expected based on the painting.

Painting 7 ''Construction of the Khavarnaq Castle'' is based on Nizami's Khamseh or five poems in which a king orders an architect to build the most outstanding castle in the world for him. After the construction, the king kills the architect so that he will never be able to build a castle better than that anywhere else. The artist here tries to depict the pain and effort that was put in to construct such a castle and the brutal reward that they were given was not fair at all [32]. Results show a low calmness and inattention and high wish and persistence. The only problem here is that physical pain has a medium value which we expected to be high.

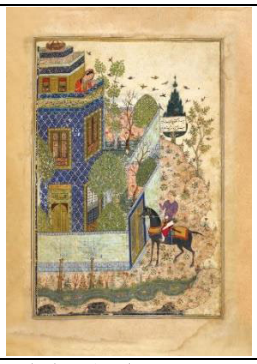
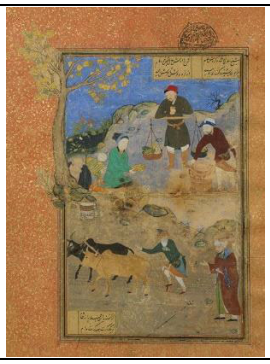
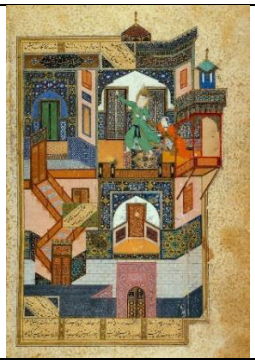
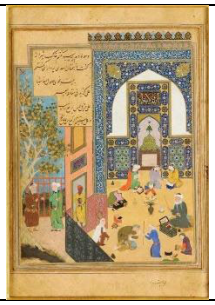
Painting 8 ''The Death of Rakhsh'' is based on the same story as painting 1 and depicts the same scene full of pain and sorrow. Results for this painting show a relatively high value for despair and physical pain and low calmness.

C. VIEWER EVALUATION

For a better and valid evaluation, we conducted a user study and asked participators to look at the paintings for some moments and rate the eight emotions on a scale of 0 to 10 based on how they feel towards the painting. The users were also notified that it is not mandatory to answer all the paintings, and if they do not have any opinion, they do not have to rate the painting. The participators of this user study were art students and professors. For each emotion in paintings, there is a minimum of 30 responses and users were not given any reward.

In Table 5 of the previous section, the black line in the figures are the mean of the user ratings and the dashed red line is the mean of the results of the five blocks. With a close look, we can see that in painting 4 and 8 the two lines are very close to each other and also the L-EEP method had poor results in painting 5 and 7 and the two lines are far from each other. In Table 6, the results of the blocks (circles), mean of the blocks (black dots), and mean of the user ratings (red dots) are visualized in the figures for each painting which can be used for comparison of results and to see the performance of the L-EEP method. We have also calculated the RMSE for the results based on user ratings that are presented for each

TABLE 4. Datset.

				Painting
Painting 1) The falling of Rustam	Painting 2) Prince Humay at the palace gates of Princess Humayun	Painting 3) Shaikh Mahneh and the Villager	Painting 4) The Seduction of Yusuf	Name
Unknown, 1330-1340 (circa)	Junayd Baghdadi, 1396	Kamal al-din Behzad, 1487	Kamal al-din Behzad, 1488	Painter
Shahnama (Book of Kings)	Khwaju Kirmani Poems	Mantiq al-tair (Language of the Birds)	Jami's Haft Awrang (Seven Thrones)	Book
© 2017 Trustees of the British Museum	akg-images / British Library	© 2000–2018 The Metropolitan Museum of Art	Wikipedia	Source
				Painting
Painting 5) Kay Khosrow slay Shideh	Painting 6) Saadi and the Youth of Kashgar	Painting 7) Construction of the Khavarnaq Castle	Painting 8) The Death of Rakhsh	Name
Qasem Ali, 1524	Kamal al-din Behzad, 1486	Kamal al-din Behzad, 1494	Unknown, 17th century	Painter
The Shahnameh of Shah Tahmasp (A King's Book of Kings)	Saadi's Golestan (Rose Garden)	Khamseh of Nizami	Shahnama (Book of Kings)	Book
Tehran museum of Contemporary Art	Public Domain	British Museum, London, UK / Bridgeman Images	© 2018 Sotheby's	Source

painting.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{8} (p_i - r_i)^2}{8}} \quad (2)$$

p: predicted value for each emotion
r: mean of user ratings for each emotion

We expected the results to improve when paintings went through case 2 compared to their results in case 1. The results of four paintings (3, 4, 7, and 8) changed in case 2. In painting 3, mean RMSE improved from 20.24 to 20.17. For painting 4, this value improved by 2.22 from 16.7 to 14.48, and for painting 7, it decreased to 26.86 from 27.51. However, in painting 8, the RMSE of the mean result increased by 0.1 from 13.15 to 13.16.

In Table 7, the overall performance of the five blocks and mean result is stated. It is obvious that mean result had the best accuracy among all, and blocks 1 and 2 also had good performance as they are close to mean result. The blocks 4 and 5 were the poorest of them all which could also affect the mean result.

As discussed before, painting 1 and 8 are illustrations of the same story. Therefore, their results can be compared as some sort of evaluation of the method. In Figure 8, overlay of the results of the two paintings which have high coverage over each other is depicted.

D. ABSOLUTE EVALUATION

For further evaluation of the method in this part, a data set of modern abstract paintings from [16] is used. This data set consists 283 images and are peer rated in IAPS standard

TABLE 5. results of paintings: vertical axis ranges 0 to 100 indicating value of emotions, horizontal axis contains 8 emotions which includes results of each five blocks, red dashed line connects the mean of five blocks in each emotion, and the black line connect the mean of users ratings for each emotion.

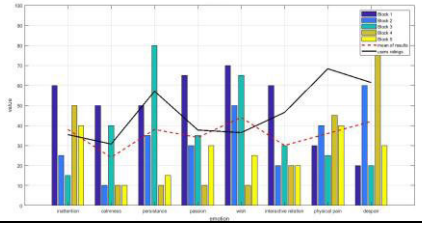
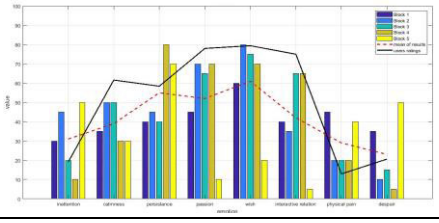
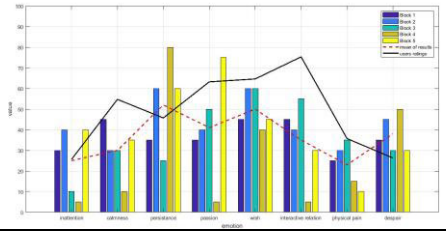
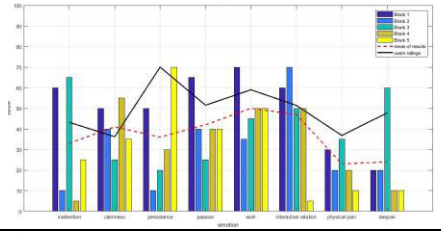
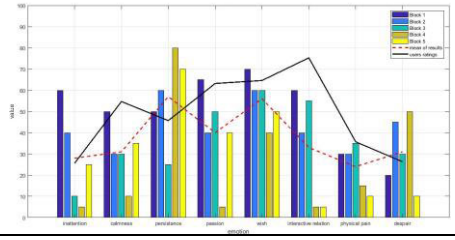
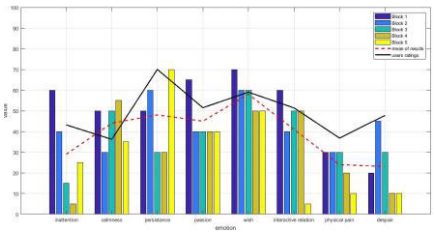
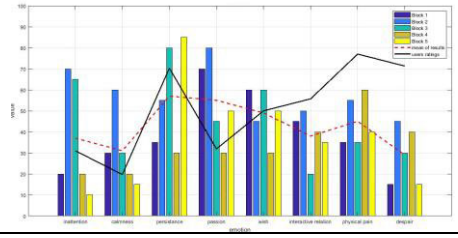
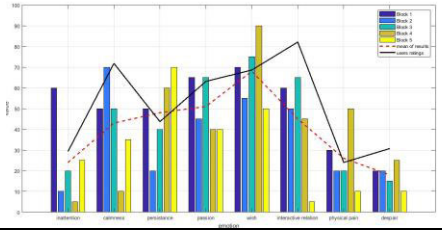
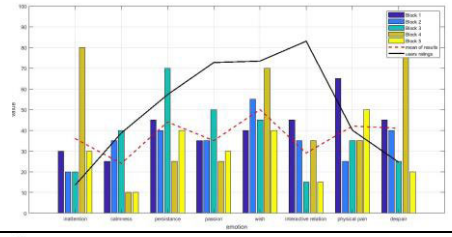
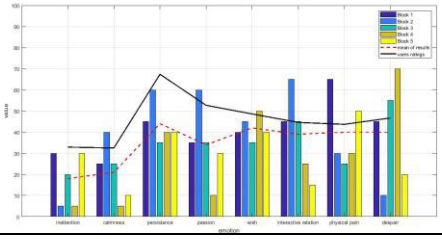
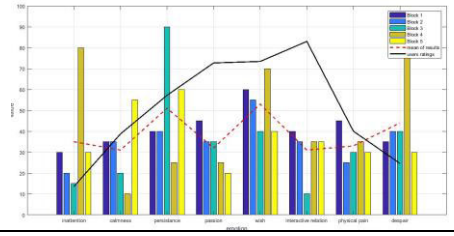
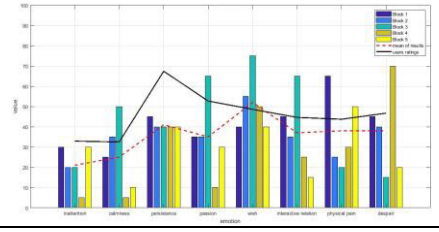
	Painting 1	Painting 2
Case1		
Case2	-	-
	Painting 3	Painting 4
Case 1		
Case 2		
	Painting 5	Painting 6
Case 1		
Case2	-	-
	Painting 7	Painting 8
Case1		
Case 2		

TABLE 6. Evaluation: the results of the blocks (circles), mean of the blocks (black dots), and mean of the user ratings (red dots) are visualized in the figures for each painting. Closeness of circles shows that results of the blocks are approximately equal and calculated the mean of the blocks as a representative of results (black dots) to compare with user ratings (red dots), also the RMSE calculated for the results based on user ratings is shown.

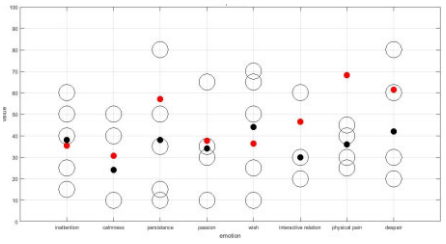
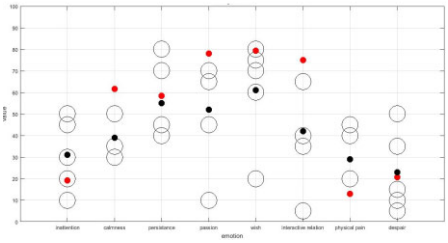
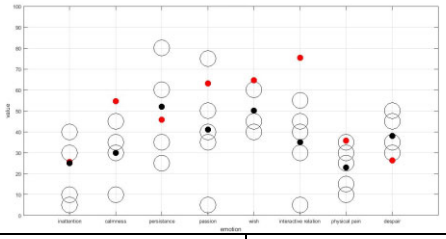
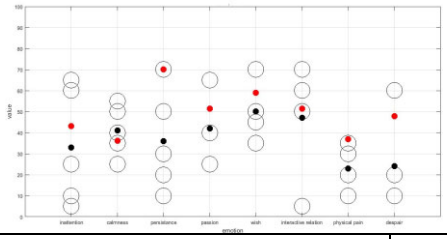
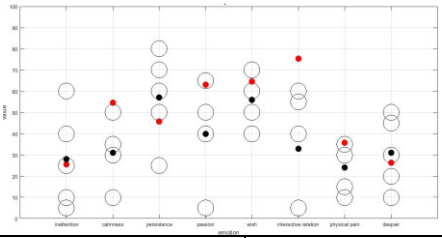
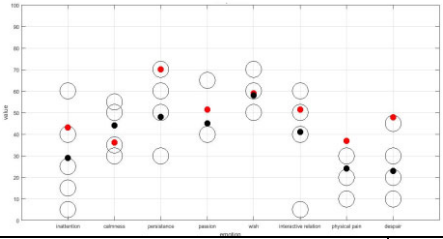
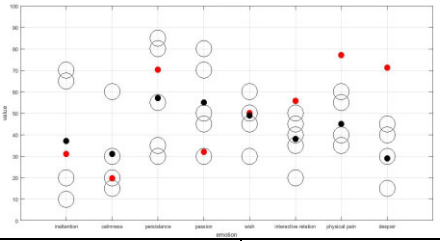
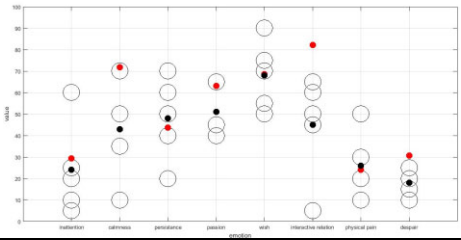
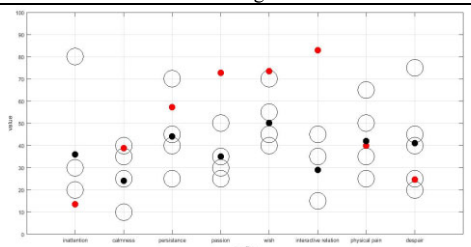
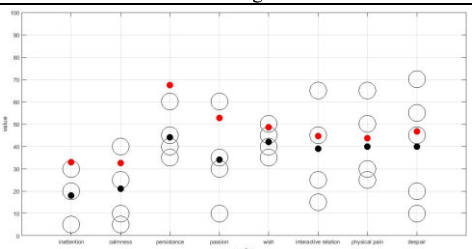
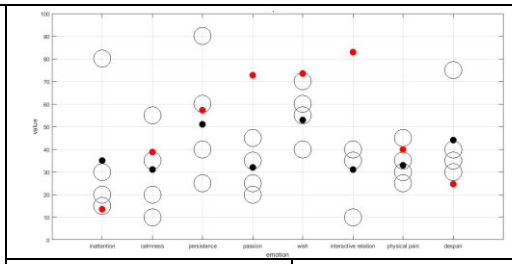
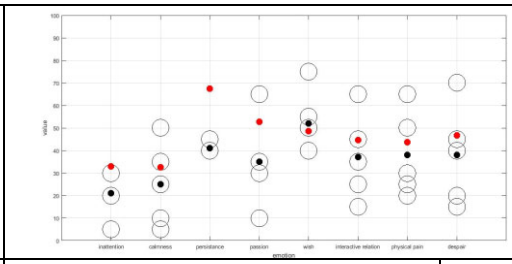
	Painting 1		Painting 2	
Case1				
	result	RMSE	result	RMSE
	Mean of blocks	16.51	Mean	19.47
Case2	-		-	
	Painting 3		Painting 4	
Case 1				
	result	RMSE	result	RMSE
	Mean	20.24	Mean	16.70
Case 2				
	result	RMSE	result	RMSE
	Mean	20.17	Mean	14.48
	Painting 5		Painting 6	
Case 1				
	result	RMSE	result	RMSE
	Mean	22.37	Mean	17.90
Case2	-		-	
	Painting 7		Painting 8	
Case1				
	result	RMSE	result	RMSE
	Mean	27.51	Mean	13.15

TABLE 6. *(Continued.)* **Evaluation: the results of the blocks (circles), mean of the blocks (black dots), and mean of the user ratings (red dots) are visualized in the figures for each painting. Closeness of circles shows that results of the blocks are approximately equal and calculated the mean of the blocks as a representative of results (black dots) to compare with user ratings (red dots), also the RMSE calculated for the results based on user ratings is shown.**

Case 2				
	result	RMSE	result	RMSE
	Mean	26.84	Mean	13.16

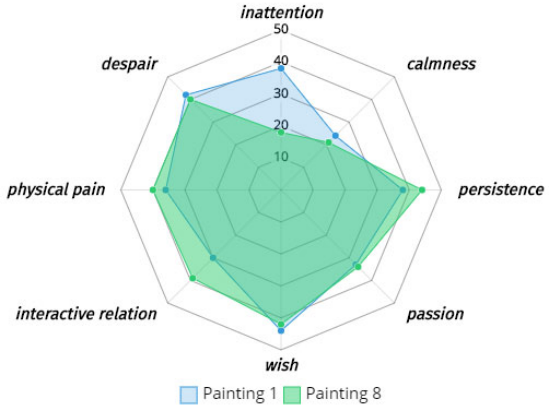


FIGURE 8. **Comparison of paintings 1 and 8.**

system. Since the ratings are undecidable for some of the paintings the number of images decreases to 228. However, in our case, as our method is based on eight colors of Luscher test, the B/W and less colored images are also omitted so the number of images we could get a result for decreased to 152. IAPS system is comprised eight emotions of amusement, anger, awe, contentment, disgust, excitement, fear, and sad. For evaluation of the results that our method produces there is a need for some rules to map the output results in our emotions to the ones in IAPS system. The rules for this conversion are below.

Amusement	If *passion* high and *despair* low
Anger	If *calmness* low, *persistence* high and *interactive-relation* low
Awe	If *inattention* low
Contentment	If *calmness* high and *despair* low
Disgust	-
Excitement	If *passion* high
Fear	-
Sad	If *despair* low

However, there was no possible rules for the two emotions disgust and fear from the combination of Luscher emotions. Therefore, we could not have any result for paintings of these emotions. The method was applied to the images and the accuracy of the method based on the rules were calculated. Table 8 shows the number of the images for each emotion.

TABLE 7. **Overall performance of the five blocks and mean result.**

Result	Mean RMSE
Block 1	20.15
Block 2	20.42
Block 3	21.04
Block 4	29.59
Block 5	28.30
Mean	19.04

TABLE 8. **Number of images processed.**

Emotions / Methods	Amusement	Anger	Awe	Contentment	Excitement	Sad
L-EEP case	23	2	11	42	28	18
Machajdik and Hanbury	25	3	15	63	36	32

The accuracy of our method are compared to those in [16] which is a successful method as it is compared to state of the art in [16]. This comparison is shown in Figure 9. As the results of this evaluation show, our method has a better performance in emotions amusement, awe, excitement, and sad. The accuracy percentage of our method are especially high in emotions excitement and sad as there is one close emotion to them in our set of emotions and the rule is comprised of only one emotion. This shows that the L-EEP method has a good recognition of emotions in its own set of emotions. In emotion anger we had a 50 percent accuracy for the two images we could process from total 3 images in this category, which is lower than the 52 percent of Machajdik and Hanbury.

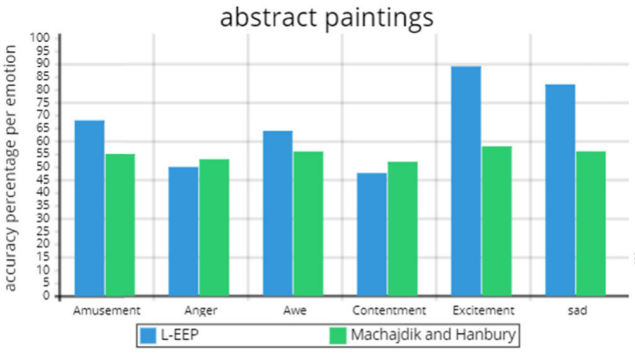


FIGURE 9. Comparison of L-EEP method performance with Machajdik and Hanbury for modern abstract paintings.

However, we are not sure how could they reach such a number for 3 images. Also, our method had a lower accuracy in the contentment emotion.

V. CONCLUSION AND DISCUSSION

In this paper, we proposed a novel method based on Culture Technology (CT) concept to extract emotions from a set of Iranian-Islamic cultural heritage paintings with the help of Image processing techniques and untouched psychological color-emotion association theory, the Luscher Color Test. Our primary purpose was to evaluate the performance of the Luscher Color Test and its blocks, in order to promote it as new emotion extraction method as it is a great tool for mood and personality analysis thus appropriate for examining abstract paintings. Also, our L-EEP method based on Luscher test is able to extract several emotions for a painting rather than a single one which can better express the paintings.

The Luscher Color Test is a simple yet powerful tool for mood analysis and is comprised of eight colors. In contrast to other methods, colors do not have a single meaning as combination and priority of selection of these colors are studied by Dr. Max Luscher for devising this test. So with a selection of eight colors from the most liked to the most hated color, this test can be done. Our idea to create a prioritized color selection from the paintings were to sort the detected eight colors by their usage and amount of pixels covered in the image of the paintings, as if a color is used more it has a substantial effect in the conveyed feeling by the painting. But this statement cannot always be true. Therefore, we created a second case in which the region of interest in paintings were detected by edge detection methods in image processing, and the test was done for the cropped area.

The Luscher Color Test consists of five blocks, first four for two-color combinations, respectively, and the fifth one for the first and last color. With the help of experienced psychologists, we converted the literal terms to numeric terms and created our knowledge base which is five 3D matrices for the five blocks.

Performance of the blocks and the mean result in the paintings shows that blocks 1 and 2 had good results, but blocks 4 and 5 had the worst results, however the mean result had the best performance among all which was also negatively affected by the fifth and fourth blocks. Based on the results of the three different types of evaluations carried out, the L-EEP metric proposed for extracting emotions from paintings indicates applicability and usability of the Luscher Color Test in the emotion extraction field. For future research, the possibility of developing the method for yielding better results should be pursued by combining other factor from paintings such as composition, texture, and shapes and maybe other psychological color-mood theories. Also, there should be an extensive study on possibility of development of multimedia retrieval systems based on content (CBIR) and emotion semantics (ESIR) based on the proposed emotion extraction method.

There are some issues concerning our work that are discussed here. First, the data set is small which is due to our need for paintings with some stories behind them to have a better evaluation of the emotions extracted. Second, the numerical values for emotions should be converted to statements with fuzzy approaches to be fully understandable. Third, the input image should have at least seven of the Luscher colors for it to get a result. However, it is possible to generate results for these kinds of images. For example, by using one or two blocks, it could affect the results, and it would not be a full Luscher result. Fourth, sometimes blocks results vary tremendously which could originate from the so-called Barnum effect of the Luscher test, and there some errors may have occurred in the rating of the statements by our psychologists. Last but not least, in the cropping phase, Iranian paintings are very detailed all over the frame of the painting and the system detects edges in margins even with the Prewitt filter. This phase can have better results in paintings less detailed towards borders.

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