

FROM PHOTOGRAPHY TO DRAWING: A SEGMENTATION TECHNIQUE FOR MURAL PAINTINGS

1. PRESENTATION OF THE PROBLEM

Diverse research areas require precise graphic representations of mural paintings, *i.e.* exact copies of the originals, which depict the graphic elements and, in some cases, the condition of the original mural, including its deterioration. This is useful to observe the figures represented by the artist as well as their components, size, relative position of their parts, and the inclusion or omission of outlines and their thickness. A precise representation also allows the study of the painting contents and the methodology used by the artist, for example the use of geometrical lines, from which his way of thinking and mathematical knowledge can be deduced.

On the one hand, the registration of mural paintings represents an important step for the restoration process of assets. These include the necessity to locate the degraded sections of a painting and the selection of the correct procedure to repair it in order to stop the deterioration process. Furthermore, recording all this information allows the observation of the conservation evolution of the masterpiece and reveals if the deterioration process continues and whether the techniques applied were satisfactory.

The easiest way to record a mural painting is by using a photograph, which provides a representation of all the information a picture can capture, and encompasses the whole visible spectrum. It gives even more information when a special film such as infrared film is used.

However, in order to register the most important information used by the restorers, it is often convenient to have a sketch of the painting, due to the manipulation and reproduction needs and because this way it is possible to include additional information such as graphics and texts. For purposes of proportion and composition studies, information about colour and tone changes can be a problem and can obstruct the observation of important information since it includes visual noise. It is also not helpful to transform it to a grey tone image since this can make the painting confusing and difficult to understand. Therefore, photography does not satisfy the entire mural painting register needs.

One of the techniques sometimes used by restorers to obtain an exact drawing of the mural consists in a footprint making. A plastic cover is placed over the mural to trace all the important elements – *i.e.* graphic representations, chipped walls, dampness, loosening of the mural coating, etc. The result is a copy with a scale of 1:1. In the specific case of Mesoamerican mural paintings,

which can encompass several square meters, the size of such drawings makes them difficult to handle and, therefore, quickly damaged with the use.

In a previous work (LUPONE, LUCET 1995), a method used to transfer this drawing to software that could handle this information was described. We used Canvas from Deneba, which permits to represent the drawings with vectors. This kind of software is similar to Adobe Illustrator, but it involves the scale references. The process consisted in transferring the original trace to a paper copy over which a grid was drawn and used as a reference to establish the scale and the alignment. The copy was then divided and printed on sheets of paper with the adequate size in order to be digitised. Vectors were then manually drawn on each part and finally all the files were joined in order to obtain the complete graph.

Nevertheless, this technique has some defects since, when tracing the original over the plastic cover, the mural can be damaged due to the inevitable contact with the surface, moreover the trace quality depends on the drawing skills of the restorer. It is also observable that if the graphic elements and the chinks were correctly placed on the copy the high precision level needed to register the width of the lines used by the artist was not obtained. Besides, despite taking all the necessary precautions, when placing again one print of the drawing over the mural in order to evaluate the quality of the results, a certain distortion was detected. Such changes might have been produced by many factors, which range from the plastic stretching to an incorrect placing alignment of the trace. Furthermore, the process was extremely slow and complicated.

Hence, for restoration purposes enough precision was obtained; but, paradoxically, the technique used could damage the masterpiece. Moreover, for the objectives of art study, precision obtained was not enough.

The method developed to solve all these problems is based on the use of photography as the initial source to obtain the necessary information to register a masterpiece without having direct contact with it. Secondly, digital processing techniques are used to obtain the required results. In order to reach a parallel copy, with no distortion, all deformations that may be caused by the camera lens or by a perspective effect must be corrected. The present work does not cover such item – which has previously been studied (LUCET *et al.* 1996) – but focuses on the process of obtaining a drawing of the outlines of the mural paintings through photography.

2. REQUIREMENTS

The methodology and tools for a correct solution must meet the following previously established basic conditions:

a) *adaptable to multiple images*: the found solution must have the quality of

been useful to paintings with different characteristics. This implies that the program has enough flexibility through the definition of parameters, which allows its adaptation and modification according to the different conditions of each painting. For instance, when studying Mesoamerican murals that have homogenous pictorial techniques, *i.e.* almost uniform outlined colour zones. However, in this case, colours can change and their homogeneity can suffer drastic modifications due to the state of preservation.

b) to the scope of many users: this software should run in economical computer systems, be in the public domain and should have a simple interface where no commands need to be typed. Solutions to resolve similar problem have been published previously. However, they were created as a computing solution and include algorithms that have to be implemented through programming (BAOGANG *et al.* 2000); therefore they involve advanced computing knowledge. Such solutions, although very valuable, are difficult to be used by restorers and art researchers.

c) input facilities: it has to accept different image formats, such as tiff and jpeg, which are most commonly used.

d) the user must be able to determine his interest points into the “image”: in order to avoid obtaining irrelevant information, the user must take advantage of his previous knowledge about the masterpiece and have the possibility to focus the segmentation process in an efficient way. For example, the program can consider a dust stain over a red background to be graphic information; therefore, it is important that such distinctions can be made.

e) precision of information: in order to obtain a precise representation of the painting regarding measures and colour, when taking shots of the mural, reference points must be taken into account to allow the effectively apply of the necessary digital correction techniques. In this case, colour precision is not a problem since a black and white image of the outlines is aimed. It is the measurement of the outlines that must be exact so that it matches with the original when placed over the photograph.

3. CHARACTERISTICS OF MESOAMERICAN MURAL PICTORIAL TECHNIQUES

In Mesoamerican culture, the integration of mural paintings in buildings was a common architectonic solution. In some cases, they were only represented as picture frames on the walls; in others, the whole room was completely painted as it can be seen in Teotihuacan and Bonampak.

The present study was carried out in Cacaxtla where eighty-three square meters of mural paintings have been discovered in the zone that has already been excavated. However, it is known that an important part of the site is still buried and that the surface of painting is probably larger than the one discove-

red since now. Only a fragment of a mural that covers an area of 2.21×2.26 meters and is located on the wall of the “portico A” of the site was examined with the purpose of carrying out the present study. It represents a quetzal and was painted around 800 AD (Tav. Xa). It was found in an excellent state of preservation, which is explained by the fact that the site inhabitants buried it with the intention of building upper constructions over the structure. In order to register this mural, restorers either traced or made rough sketches of the painting.

The pictorial technique found in this and in other sites remains constant, although it is not certain whether it was distemper or fresco. At a glance, black outlines around uniform yellow, blue and white surfaces of colours can be seen. Such outlines delimit the figures over a red background. These lines were drawn again after applying the colours in order to assure a clear shape of the forms. The material over which the painting was drawn is uneven stucco.

The painting representation to obtain must reveal all the details of the figures using only black lines. In most cases, it matches the black outlines, which delimit the colour areas. But it sometimes corresponds to the boundaries between two zones painted in two different colours. In the first case, it results in a well-defined line with a certain width and in the second case the line is only symbolic and has no width.

A more detailed observation of the mural showed that this light definition of the contours could vary. Besides the black outlines, there are also red lines drawn inside the yellow areas, the quetzal beak and wings, and inside the blue zones located on the right side of the painting. In several parts of the mural one of the colours invades the area of another colour next to it, as if the paintbrush had slipped out of the hand of the artist. This can be observed in the blue part of the quetzal wings, which invades the yellow zones of the upper part. Another exception to the rule is the presence of a *pentimento* in front of the beak of the bird where the black outlines were covered with red, perhaps with the intention of erasing them or maybe just to make them subtler. Moreover, a close-up shows that the colours are not so uniform and that they present small variations due to the technique used when applying them.

On the one hand, the feature of this painting where wide zones with only one nearly uniform colour is observed simplifies the segmentation process. Therefore, it is possible to represent the mural with a sketch made only with lines, which is not the general rule in the art of painting. For instance, this would not apply to a painting by Monet. On the other hand, the texture of the stucco and the state of conservation of the mural coating complicate the segmentation process. For example, on the right side of the mural, we can observe missing parts in the pictorial layer, and two already repaired crack.

Therefore, the black outlines disappeared and the colour of the surfaces is no more uniform (it appears to be stained). In other parts of the painting, important stains are observed, mainly on the red background and the blue zone located on the left side of the image. This produces a visual effect similar to the one produced by the cracks, although it is expressed in a different colour.

Finally, in an enlarged portion of the mural, it is shown that the rugged texture of the mural coating alters the colours. This could be due to the erosion of the most pronounced beaks, the accumulation of dust in the hollows or simply to the reflection of light on certain parts of the painting that creates shadows. All these details imply different pixel values and make segmentation more difficult. Therefore, such elements could be considered as important graphic elements by the program. In the case of small colour variation because of dust or texture, it is preferred not to have them registered, but large missing parts or cracks should appear in the final representation of the painting (Tav. Xb).

The image was digitised using the Kodak PhotoCD system. Its size is 2881×1985 pixels, which gives a resolution of approximately 7 pixels per millimetre of mural painting. Unfortunately, there was no control over the digitalisation process so the software program automatically blurred the image.

4. SEGMENTATION PROCESS

The techniques used for the segmentation of an image between its different components can be divided into three groups. The first group consists on separating pixels with certain value ranges and is based on the image histogram. The second group, also called *edge detection*, is based on finding sudden changes in the pixel values, assuming that such alterations represent an information change. Finally, the third group known as *region growing and merging* consists in planting seeds into the image, these start growing, merging the surrounding pixels that resemble them according statistic calculations.

In the first case, with histogram threshold, the wide range of values that pixels in the same area can reach makes it difficult to obtain exact results. Edge detection generally leads to an over-segmentation of the image since this technique immediately detects any change in colour tones and results in very fragmented boundaries. Finally, the problem with region growing and merging consists in the selection of the initial seeds to grow.

These techniques were originally developed for grey scale images, and they are combined when colour images are analysed. Calculation on grey images is faster but in the case of mural paintings, colour images give a more complete information than monochrome images. In grey, the quetzal appears to be composed of only three tones: pale, light and dark. Besides, the black

outlines disappear and combine with the dust and rough surface of the mural painting.

From the techniques mentioned above, the first and the third ones are the most used since, when combined, they give a more precise result.

In order to divide the image into its different colour surfaces, we used Multispec, a free software developed by the University of Purdue, which is available through Internet at <http://dynamo.ecn.purdue.edu/~biehl/MultiSpec/>. This software was created with the aim of processing the images obtained from satellites and it is constantly updated and improved to include the latest detection techniques resulting from research in remote sensing. These images register a wide range of spectral length – from ultraviolet to infrared – and are composed by several channels each one containing only a small portion of the spectrum. When analysing paintings, only the visible information was used, but the three channels R, G, and B, necessary for the digital description of a colour, transform them into a multispectral image. A future study will include infrared wavelength in order to capture additional information and obtain more precise results.

Like in mural paintings, satellite images also show colour variations to represent elements with similar characteristics. As a result, Multispec creators designed a special procedure to optimise the quality of the results and reduce the process time. The first step of this course of action is “teaching” the program what information the user wants to get, this is called the training phase. The user has to manually mark the characteristic zones and to classify them into different categories. For example, in this particular case such categories correspond to red, blue, yellow, black and white colour elements; additionally we registered as categories the *pentimento* – red over black – and the repairs the restorers made to preserve the mural and the loosening of the pictorial layer, which are represented in grey. The possibility to do this manually permits the restorer to use his knowledge of the problem, his perceptive quality in order to describe what he is looking for. Therefore, the resources are optimised and no more random search is necessary, eliminating garbage production and time losing.

After this has been done, the program analyses the different categories and extracts the defining spectrum characteristics from each one of the R, G and B channels. Then, it divides the pixels into different categories using statistical calculations to classify the images. For this purpose, parameters can be established and statistical techniques can be selected resulting in more accurate calculations.

Initial classifications usually present certain mistakes maybe due to the fact that the training zones defined by the restorer do not allow for a precise description of what he is looking for or because some important categories were ignored. For instance, if deterioration is not considered an important

matter and thus it is not included into the category definitions, when classifying paintings it will result in a set of pixels that won't be correctly located. The program will try to include them in the more similar categories, making a mistake and contaminating their definition. Furthermore, the final segmentation will have a lot of noise.

The program offers special tools to detect the most problematic zones. For instance, it can produce a probabilistic image where the certainty of classification for each pixel can be measured. It is possible to check the histograms of each initial zone as well as the precision level obtained to classify zones and categories.

With this information, learning zones are corrected, categories are either included or excluded, and the image is reclassified. The steps are repeated until the aimed results are obtained.

5. SEGMENTATION OF THE IMAGE INTO COLOUR ZONES

Fig. 1 shows the high quality segmentation obtained applying the described methodology to divide the image into different colour zones, though some pixels seem to have been placed in incorrect areas.

Although most of the outlines appear in the black area image, there are some missing, mainly the boundaries between the yellow zones and the red background. For example, the outlines of the upper part of the wings, the beak and the feet of the bird do not appear in the image since such lines were classified under the yellow or "red over black" zones. Therefore, so as to obtain the entire outline information, the red and the *pentimento* images should be included. The thin lines on the feathers of the wings are not clear and tend to disappear.

Quantitative calculations in order to compare the relative weight of each colour can be done if the image is divided according to its different components.

Tab. 1 shows that the red zones cover fifty percent of the composition and that the blue zones cover a twenty-five percent. In this particular case, this information is not relevant to the study of the mural painting since it is only a fragment that is being analysed. Nevertheless, different paintings could be compared using this method and it is also possible to find out if their relative weights are repeated. Besides, the mural measurements can be deduced since the image resolution is known (7 pixels = 1 mm).

In addition to the quantitative method, colour fragmentation can be used to visually evaluate the balance of the composition and the relative weight of the different colour zones. It is also possible to analyse the continuity of a colour as well as its distribution. For instance, the pyramidal use of the yellow tones above the quetzal is observed.

Feature	Number of pixels
Black	556534
Black on red	324243
Blue	1266422
Red	3047447
Restoration	104209
White	125344
Yellow	294586

Tab. 1 - Amount of pixels in each colour zone.

The *black* colour separation image includes some pixels that should have been classified into the blue zones but correspond to stained parts of the mural. This can be observed in the feathers located on the right side of the image. The same thing happened with the deteriorated areas of the wings and the background.

In the image corresponding to the classification of the surfaces painted in *red over black*, many outlines that separate the figures from the background were included. This is justified by the fact that the last step of the process consisted in painting the outlines all over again after applying the colours. Many of the “dirty” parts of the red background were also included in this category.

In the image where the *white* areas were grouped, the white part of the eye was perfectly included, but so were the sections of the mural where the plaster is loose.

The classification of the *blue* areas was not complete since some of the pixels that corresponded to this section were grouped in the black zones.

The *yellow* category was well defined, however, there was a little interference with the red background. Also, some sections where the colour was extremely pale were classified in the white section. When the yellow painting was “dirty” it was grouped in the “red over black” category. Nevertheless, these defects are generally isolated and do not alter the segmentation of this category.

Classification of the *damaged and repaired* zones was good enough, although there is a series of pixels that follow the figure outlines and do not correspond to this characteristic.

In the image where the *red* areas were included, some pixels are missing. However there was no extra information.

In the blue wings some sections invade the yellow zones; this can be explained as the technique used by the artist to create green tones to colour the edge of the wings or as a *pentimento*. Another possibility is that the paintbrush slipped out of the hand of the artist. In this case, the program did not make a mistake but made a detail that was being unnoticed more obvious.



Fig. 1 – From top to bottom and left to right: fragmentation of black, blue and red, repairs, overlapping of red and black, white and yellow.



Fig. 2 – The image after an edition process to clean the background.

6. THE DRAWING OF THE CONTOURS

The overlapping of several images containing information about colour separation affords a drawing that shows the image contours. The information concerning the damages of the paintings was allowed to remain within the body of data since it supplies a more complete and precise description of the all painting. However this information could have in principle been left aside. On the other hand, the damages allow the understanding of the interruption of black lines which is important, mostly in the case of major missing as it occurs on the right side of the paint.

After the step of visual simplification is completed, depending of the ultimate use that image will have, the obtained contour allows for complementary processes such as its vectorization using programs such as Adobe Streamline, as well as its edition using Adobe PhotoShop in order to obtain a clean drawing of the painting (Fig. 2). It is also possible to go further beyond if a perfect graph is necessary. In order to achieve that, it might be necessary to eliminate the stain and dust that remains in painting, eliminate the missing parts, redraw them, and finish the contour lines. This is an additional step that requires care in his execution and that can hardly be automated since other criteria besides the mathematical are required.

7. CONCLUSION

The drawing obtained with the described process offers many advantages, it is a faithful reproduction of the original and includes information which is impossible of been incorporated from footprints i.e.: the damages,

the precise representation of cracks, the loss of the pictorial layer and the width of the contour lines, all details that given their size and quantity are difficult to reproduce. The precision level of all this information ultimately depends on the quality of the image, from the quality of digitisation and from the application of correction to parallelism prior to the application of techniques for the detection of contours.

At the present problems are found concerning the quality in the detection of contours. For example, the small central lines in the feathers of the wings were not adequately registered. Further work to improve the result is considered. It will explore the use of a wider wavelength spectrum that may include infrared zone and the improvement of the digitisation system.

The present solution matched the initial requirements of simplicity, economy and the process is easily transportable to other case studies. It also demonstrated to be adequate to the characteristic of Mesoamerican paintings and a friendly tool easily accessible to restoration professionals and art historian.

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ABSTRACT

In this article the authors present a method for obtaining a line-art representation of a mural painting using colour photography. First, the information concerning colour components was separated and then the contours of graphic representations were extracted. The result is an exact copy of the original and this level of precision makes it an important solution to the problem of registering and recording mural paintings. This method has been shown to be a useful solution for the documentation of the state of conservation of paintings, as well as a means for keeping track of restoration work; furthermore, it provides a fundamental material for analysing paint compositions. The present approach was developed keeping in mind the possibility of usage by computer non-specialists; no programming knowledge is assumed and the use of shareware software was always preferred.