Abstract

This paper presents a new method for zooming out an image. As the Impressionism is one of the most complete painting technique, able to preserve notably details, light effects at a close or far range, we propose a method based on an impressionist approach. The input image is analyzed and described through impressionist characteristics that will be preserved when a zoom out will be realized. We created a set of characteristics of images and the corresponding algorithms to compute them. These characteristics are then used to build a set of zooming out algorithms. To validate the process, the zooms out have been applied to different types of images: photographs of paintings and other photographs. Results prove that this approach is more suitable than existing ones.

1 Introduction

We propose an impressionist approach to visualize very high resolution images at different scales.

Most of the image acquisition systems have a higher resolution than devices used to display images acquired. For example, in 2008, most personal digital cameras have 10 mega-sensors ($3648 \times 2736$) while personal display devices have only 1.2 megapixels ($1280 \times 1024$) and typical cathode ray tube or LCD computer displays range from 67 to 130 PPI (Pixels Per Inch). To display an image with a higher resolution than the display device, we need to zoom out the image.

Zooms implemented in image manipulation softwares (Gimp, Adobe Photoshop) are based on the computation of an average value of the colors of a few pixels. More than zooming out images these techniques blur them. Significant details are henceforth blurred and sometimes disappear. We propose a library of zooms able to preserve the details on image. It is based on the impressionist art of painting.

The impressionist art of painting came after the achievement of photorealistic painting (see La leçon de musique (Royal Collection Saint-James’s palace, London) by Vermeer (1632-1665) or Ville d’Avray (National Gallery of art, Washington D.C.) by Corot (1796-1875)) and benefits both of earlier techniques of painting and of the recent, at the time, photography.

The impressionists painters developed a radical new painting technique with busy brushstrokes and use of vibrant colors. It is one of the most accomplished technique of painting where realistic scenes are realized. Details are very present in impressionist painting and are clearly visible at a close or far range. This is a visual effect that was researched. As impressionism is one of the most complete painting technique, we propose to create an impressionist approach to preserve details on an image when zoomed. A library of zooms based on the main characteristics of the impressionism is presented. These zooms can be applied to any images. To realize these zooms, we present a scientific approach of impressionist painting techniques and theories and we create a set of specific algorithms to compute the characteristics of images.

In this paper we present first the related works. The impressionism techniques that painters used is then described. We adapt the most significant of them to computer graphics image analysis. Based on this, we propose a new zooming out system. Finally results and images are presented.

2 Related Works

A lot of previous works have been presented on computer graphics and impressionism. Generally they focus on the generation of impressionist paintings on computer [6, 24, 23, 2]. These works are classified in Non-Photorealistic computer graphics. These models can be based on the simulation of physic dynamics involved in the painting process and are then designed to accurately reproduce the painting process, strokes per strokes. The support, the media, the tool and their interactions are then modeled.
Even for 2D model [13, 18] rare are those who analyze the style of the existing paintings to propose a model. Only Yang et al. [28] have proposed a model based on an analysis of Seurat’s pointillism to generate a non-photorealistic rendering (exclusively dedicated to Seurat’s rendering).

Recent authors have proposed algorithms for the analysis of painting based on art theorists. They focus on some specific quantifiable features in the paintings that could be useful for their classifications. [16, 17] focus on the brush strokes. [8, 7, 9] focus on the Italian renaissance period (painting, perspective and reflection effect) and have proposed an analysis of these paintings. Some of them are used to verify some art historian theories [20, 15] or to restore paintings in museum [3, 11]. Unfortunately, the aims of these works are the analysis of the image and these results are not used as an input of a new process.

3 Impressionism techniques

The impressionist painting is characterized mainly by visible brushstrokes, open composition, emphasis on light and color arrangement. In fact impressionist painters emphasized vivid overall effects rather than details. Short brush strokes of pure and unmixed color are used in order to achieve the effect of intense color vibration. For an impressionist painter the optical mixture in the eye replaces mixture of the pigments in the pallet.

3.1 Composition and framing

The composition is the combination of elements in a painting (or other work of art) that provides order or structure to the scene. The compositional rules vary among painters, styles, movements and times. The artist determines what is the center of interest of the picture and composes the elements accordingly.

The impressionists had a traditional approach to the composition, which is to put the main subject at the center of the eye of the observer. A lot of impressionist paintings obey to the rule of the third. The principal point of interest is located at the intersection of imaginary lines traced vertically and horizontally at a distance of approximately a third of the edges of the work. These lines determine the natural tension fields of many paintings. The rule of the third is used in the landscapes and the portraits for example.

They can give us an indication of the division in successive planes of the paintings. Most impressionist paintings are composed of almost 3 different planes named foreground, middle ground and background. As mentioned in [21], the impressionists relaxed the boundary between subject and background so that the effect of an impressionist painting often resembles a snapshot.

The figure 1 presents the *Coquelicots* by Monet. Remark that the big tree, the top of the person at the foreground describe two of the imaginary lines. This painting is composed of two planes (foreground and background).

3.2 Light

Lighting is mainly used to create volume on paintings. Impressionist painters used it to depict a “moment of the journey”. The light effects are very present: light is emphasized and reflection of colors from object to object are detailed. One major characteristic of the impressionists is that they painted outdoors much of the time [25]. Landscapes are no more realized in the painter’s studio but are made outside directly in front of the scene (i.e landscape with weather and light conditions) to be represented. Impressionist painters represent also variations of light. For example in *Le Bal au Moulin de la Galette* by Renoir (see figure 2), there are patches of light on the ground that represent the sunlight not obscured by the trees. The impressionists had observed that the shadows in the outdoors are not blacks, they depend on the effects of the light. The impressionists painted shadows in blue, violet or lilac.

Moreover, they painted the same scene at different times and in different weather, see for example, the set of paintings of *La cathédrale de Rouen* by Monet (Musée d’Orsay, Paris). They had to work fast to capture the moment, or to finish an outdoor painting before the lighting conditions changed. Due to these constraints, impressionist painters adopted a distinctive style of rapid, short broken brushstrokes.
3.3 Theory of color

Advances in the fields of optics and color theory fascinated the impressionist painters and they applied scientific principles:

- Contrasting primary colors and complementary colors.
- Colors are applied side-by-side according to the law of Chevreul [5]. He noted that the difference between two colors are intensified by their juxtaposition. This law of simultaneous color contrast changed the way color was used in art. Chevreul’s work influenced the movement in art known as impressionism and Neo-impressionism.
- They use the effects of contrast described later by Johannes Itten [14]. Johannes Itten identified 7 contrasts of color: hue, light and dark, cool and warm, complementary, simultaneous contrast, saturation, proportion.

Cézanne is well known for his color’s work (see figure 3).

3.4 Elements of perspective

In the art of painting artists simulate the appearance of three dimensional space on two dimensional surface. The impressionist painters simulated the effect of perspective by:

- a graphic construction (linear perspective). Distances are build by the same objects (characters etc.) diminution.
- the chromatic perspective. Colors of the foreground are very different while at the background colors are neutrals. The richness of color in the foreground contrast with the receding intensity of the color in the background.
- opacity-transparency. The transparency suggests the distance. Some elements of the scene uses transparency letting the background image show through. This opposition is used to depict the distance.
- the contour suggests the difference between zones presenting the same optical criterion.

Cézanne is well known for his color’s work (see figure 3).

4 An impressionist characteristics approach

Based on the impressionism techniques presented above, we propose in this section an implementation to determine the main impressionist characteristics of an image. Note that it consists on an impressionist approach that can be applied to any image (not only impressionist images).

4.1 Color space conversion

As a preliminary step, we need to represent our image in different color systems. So we select several color systems: RGB (Red, Green, Blue), HSV (Hue, Saturation, Value), CIELAB and the standard $L_1$ [1].
With the classical color representations (HSV, HLS) the saturation is not necessarily low-valued for achromatic pixels and chromatic and brightness information are not independent. The works of Hanbury and Serra [10, 12] have shown the drawbacks of the use of these color representations in image processing. In $L_1$ each components luminance, saturation and hue is processed independently. The $L_1$ space transformations are linear and include a linear approximation of the hue. Angulo and Serra [1] have shown that $L_1$ is adapted to the image analysis. In the representation “luminance, saturation, hue”, it is possible to use saturation as stabilizing element to segment the images. The saturation measurement is used in the calculation of a saturation-weighted hue statistics and of saturation-weighted hue histograms. This norm is suitable for the hue statistic computations and is appropriated to the analysis of painting.

A lot of statistic measures are automatically computed: average luminance in $L_1$ norm, extrema value, median value... and are considered as important features of the image.

### 4.2 Composition

We design a method to compute automatically the composition as in the impressionism techniques. We use the rule of the third that gives information on the image division in different planes. This is achieved easily by dividing the image in 9 parts.

Moreover as described above, the color composition can also be used to improve these results. This color composition is realized according to the luminance of the color used on the painting.

Let a **various zone** be the area of the histogram between two consecutive minimum. We use the $L_1$ color space and we find the color composition automatically as following:

1. Compute the luminance histogram.
2. Find the extrema (i.e minimum and maximum). Note that local extrema are ignored.
3. Search the different various zones on the histogram.
4. As we should find almost 3 different planes, if we obtain too many various zones at the previous step, the average luminance (see section 4.1) is used to select the three various zones. The three various zones selected have the closer distance between their minimum and the average luminance.

Remark that with the color composition, we can determine easily the skyline. In linear perspective, the horizon is the line where sky and earth seem to meet (note that it is on this line that the vanishing point is located). In our case, the horizon is an average horizontal line which separates the background and the middle ground (if it does not exist, the foreground is used).

### 4.3 Light

In our algorithms lighting characteristics are determined automatically. The histograms hue/saturation and luminance/saturation allow us to separate achromatic and chromatic information. A logarithmic scale is used for the luminance/saturation histogram to easily identify characteristics. In the photographs, the areas of reflections result in alignments in luminance/saturation histogram [1]. These alignments correspond to a constant color and occur when on an area $Z$, hue is constant and saturation corresponds to the same value: the average RGB value for a pixel minus the median RGB value for the same pixel is constant [1]. Applying these results on impressionist paintings, we note that the light zones are associated to the reflections and the dark zones correspond to the shadows. In the painting, light and shadows are independent of the hue. These two histograms are used to characterize the image.

### 4.4 Perspective

We have also to approximate the vanishing point. The vanishing point is the point towards which a set of lines that are parallels in the scene, seems to converge in the image. Two or more aligned vanishing points define a vanishing line. In mathematical terms, a vanishing line is associated with a set of parallel planes in the scene. Criminisi, Kemp and Zisserman [8] have proposed a solution based on art theory for Italian Renaissance painting to vanishing point. It consists on extracting the contours of the image with the Canny edge detector and fitting straight lines to
the computed edges and searching their intersection points. We try to apply this method to impressionist painting but it does not work as the painters realized quickly their paintings, the construction of the painting is realistic but not mathematically correct (cf. section 3.4).

As mentioned by [8], any disproportion is intentional and so corresponds often to a perspective effect intended by the artist. So our approach is to compare objects (peoples for example) placed at different distances from the viewer. Moreover the difference in brightness between the areas of the image is also used to establish a progression. We use also the skyline to approximate vanishing point (cf. section 4.2). This solution requires that a user selects the same object at two different places and that should be improved.

4.5 Study of color

We have created tools to locate contrasts present in a painting. These tools compute a color map, complementary color, temperature of color, dominant hue and are used to analyze the palette of colors. A palette is the selection of paints used to make a painting. They determine all the mixtures and color effects of the image. We want to highlight all the contrasts defined by Itten [14].

These tools are applied on all the image or to determine color juxtaposition on part of image by displacement of window.

A color map: the visual color wheel. A color map represents all the colors in the painting without their proportions in the image. The darker colors are nearer the center. With the color map we can research the oppositions of colors. For the same hue we research the oppositions light and dark. The color map outlines the color space of the painting. With the color map, we can analyze the transition of color.

We define the gamut of color which is a set of colors in color map considered as representative of the painting.

We select the most saturated color and the purest color. In the color wheel, we select the extreme points (visually near to the center or contour of the wheel).

Monochromatic color harmonies correspond to hue that varies only in saturation and value. Analogous color harmonies are hues that are next to each other along the circumference of the color wheel. Triadic color scheme is three colors spaced equally around the color wheel. Tetradic is four colors forming a rectangle on the color wheel. These two complementary pairs form the two diagonals of a rectangle or square on the color wheel.

A complementary color. We locate the use of complementary colors. The Newton’s definition of complementary color is any two hues that, mixed in the right proportions, produce a neutral (pure white, gray or black) color. The impressionists used a simple color-circle to choose the complementary color. As mentioned by Yang et al. [27] the Chevreul’s color-circle, divided in 72 parts, is well-adapted to find the complementary color on an impressionist painting (for a given color, the complementary color is diametrically opposed on the circle). As Yang et al. did with Seurat’s painting we use the Chevreul’s color-circle to determine the complementary colors.

Temperature of color: balance of warm / cool colors. The warmest hue is usually a red orange with a CIELAB hue angle between 35 to 45. The coolest color is a complementary contrast to the warmest hue. The coolest hue is usually a blue green with a CIELAB hue angle between 215 and 225. The warm/cool contrast defines a relationship between warm hues (from yellow to red/violet) and the cool hues (from yellow green to purple). In the HSV model, the warm colors correspond to a hue value included [0, 90] U [270, 360] and the cool colors have a hue value included [90, 270].

To compute these values, we have to divide the image into regular parts, hereafter called “windows”. The size of the window, n × n, depends on the resolution of the image. For example on a 10M pixels image, we used a n equal to 15. This value can be given by the user. For each window of the image, we calculate the average of the hue values of its pixels and the most frequent hue value. When it’s done for the whole image we compare the values obtained with these of the neighbour (8-connectedness) windows.

Dominant hue. The dominant hue is the average of the value H or the median value H in the image. If we compute the average of all the hue values of a painting, the dominant hue is not significant. This happens because the colors used by a painter are not homogeneous (see L’Eglise d’Auvers sur Oise by Van Gogh (Musée d’Orsay, Paris)). We associate the notion of dominant hue with the notion of homogeneous color region. We combine the value of the hue with the saturation.

Itten’s Contrast These contrasts correspond to a ratio between the color of a point and the average of colors on a window on this point. We measure the differences of saturation, brightness and hue. We use the previous elements (study of the color) and we compare different areas of different sizes to determine these contrasts. This is achieved automatically and we can find both local contrast and global contrast according to the sizes of the areas. These measurements allow us to locate contrasts in a painting. We seek the contrasts of color identified by Itten [14]: contrast of hue, contrast of light and dark, contrast of warm and cool, contrast of complements, simultaneous contrast, contrast of saturation, and contrast of proportion. Note that we obtain a map of contrasts for an image (i.e for each pixel or window we have values of contrast). It can be used to improve the segmentation of the image.
4.6 Region

We detect the regions automatically on the paintings. The first step is an edge detection based on a Sobel kernel filter [22]. The edge detection enables us to extract the most significant lines from the image and permits to detect also the framework of the painting.

To detect areas, we use the notion of homogeneity presented by Celnek [4] and Tremeau and al. [26]. From the image of homogeneity, we associate a label for each pixel of image. An area is depicted by a set of pixels which have the same label. These areas constitute a first approach for the region detection. Based on the methods of Ren and Malik [19] we improve the region detection according to the criterion of brightness and saturation. This segmentation allows us to isolate patterns and repetition.

4.7 Zooms

We have created a collection of zooms. Each of them preserve one of the described characteristic. In this section, we detail the general form of the different zooms. In the following, \( I_S \) denotes the image source (image in high resolution), \( I_D \) the image displayed (after the zoom out process).

For each characteristic described above, we produce a map corresponding to the characteristic researched on \( I_S \). For example, a map of contrast is produced: for each window \( W_S \) of \( I_S \), a value is computed according to the Itten’s contrast between \( W_S \) and its neighbours. We produce also a map of contours, a map of composition, a map of light, a map of perspective and a map for each part of study of color (temperature, complementary...).

We have developed a zoom for each map previously presented. The user gives a ratio \( n \). A pixel \( P_D \) of \( I_D \) is computed using a window of \( n \times n \) pixels \( P_S \) in \( I_S \). We use the map associated to the zoom selected to compute the color of each pixel of \( I_D \). For example with the warm/cool contrast, we have computed two values (the average and the most frequent values) and therefore two pixels will be displayed in the new image. Two problems remain:

1. The ratio might be improved. Sometimes a \( n \times n \) region is too big for the effects expected, sometimes it is smaller than a single brush stroke.

2. It is still possible to use \( n \) as a rational non integer number, or to use a non square window.

We propose a solution for the second problem. If \( n \) is not an integer, or if the window used is not square we have to associate a weight to the value of the pixels of a window. As mentioned above, we consider a window of \( n \times n \) pixels \( P_S \) in \( I_S \). This factor is proportional to the coverage area of the window on \( P_S \).

Remark that we apply always our zoom out process on \( I_S \). As we have computed a set of characteristic values of \( I_S \) we never modify these informations. We compute one time (it can be achieved when loading the image) this set of elements and we use it to zoom out with different ratio. So the user can realize successively two or more zooms out.

The zoom(s) chosen preserve the main characteristic found. For example if the balance of warm/cool colors is very important, the zoom chosen will preserve this characteristic (i.e pixel colors selected during the zoom process will have the greater warm/cool color difference).

Note that different zooms can be used simultaneously on different part of \( I_S \). For example after a region decomposition, each region can be zoomed out with a particular zoom. As one can imagine, this operation can be also achieved on the foreground, middle ground and background. Remark that the use of a contrast zoom for the foreground and a average zoom for the background enhances the composition of the photography.

4.8 Automatic impressionist characteristics detection and results

As a preliminary benchmark, we have tested this set of elements on a database of impressionist painting images. This database is mainly composed by high resolution digital photographs of impressionist paintings located at the Musée d’Orsay (Paris, France). Our program starts with an image and computes a description of the input image according to the set of elements. Then a list of zooms is automatically proposed (depending on the obtained description). Remark that the user can choose one of them manually for each part (region, composition) of the image.

The figure 5 presents the result of the composition. The first planes obtained by the decomposition on the Champ de coquelicots (see figure 1) by Monet is shown. As one can see, two planes have been detected (the foreground is unchanged while the background is represented in black on the figure).

To illustrate the light detection, we applied our method on Le berceau by Morisot (see left part of figure 6). On the right side the image presents in blue the effect of the reflected light. Finally we illustrate the study of color with Cezanne’s paintings. It is well known that Cezanne uses colors diametrically opposed on the chromatic wheel. For La montagne Sainte-Victoire by Cezanne (see figure 3) we present the visual color map wheel on the figure 7. Note that the geometric construction of the paint can be highlighted by our region detection.

As the characteristics researched are present in the impressionist painting, our analysis is adapted to impressionist paintings. This permits to choose one zoom that preserves these characteristics to zoom out the image. In the follow-
5 Results

In this section we present some zoom out realized on digital photographs of paintings and of our university with a very high resolution and definition. According to the method described above, we use the most adapted zoom to each digital photograph. For these results, the user has determined what characteristics would be preserved and chose one of the zooms available. Note that this choice can be realized automatically and that we can apply different zooms on the different parts (regions cf. section 4.6) of the image.

The top of the figure 8 presents a detail shot at close range (3 inches) of L’Eglise d’Auvers sur Oise by Van Gogh (Musée d’Orsay, Paris). We realized two zooms of the photograph to obtain images with lower resolution than the original: a Gimp zoom at bottom left and our zoom at bottom right of the figure. As one can see the left image is blurred while an impressionist approach gives better results: the details are almost preserved like brush strokes and contrast. Moreover, on the right image, the colors are brighter. One can see the blue strokes on the grass and even the yellow flower still appears with our method.

The figures 10 and 9 present results of zooms out of photographs. The top of figure 10 presents the original photograph (3072 × 2304). The following image is the result obtained with GIMP when the image is re-sized (192 × 144). As one can see the image is blurred. Moreover the cubic interpolation produces artifacts. For example a white segment appears at the bottom left of the image. The third image is
the result produced by our system in which the contrast was preserved. The image looks more like the original. The two last images are the result of our zoom out system with different values of contrast and scaling. The image on the bottom left is based on a 25% zoom out on each image dimension. With a magnifying glass, one can see that it is still very close from the original. To notice a real difference one has to magnify four times our zoomed out image, that is to increase its size to the size of the original image. Note that the image is given as a file of only 7.2% of the size of the original image (1,672,352 instead of 23,217,128 bytes).

Figure 9. Illustration of composition detection on photograph.

Figure 9 shows an example of treatments realized according to the composition detection. The first image is the original photograph. The two last images present the result of the region detection and of the zooming out. The regions are the road, the sky (represented in black in the image), the tree and the buildings. We have decided to apply two different treatments to zoom out: regions represented in black are zoomed out with an average zoom; for the other regions, the zoom out system preserves the contrast.

6 Conclusion

In this paper we have presented a new technique to improve the zooming out of pictures. This method is based on an analysis of Impressionist paintings and techniques. This analysis was tested both on photographs of paintings and on simple photographs. We have proposed an application (zooms) that uses our classification. We have extensively tested these zooms on photographs of paintings, where they worked quite well and on photographs where the results are surprisingly good. An interesting side effect of our work is that it leads to a new way of compression of images. With a ratio of 7% compression the images compressed are still of good quality.

Further works will be done to improve the vanishing point detection. Moreover we will create a database of elements of classification for paintings. It will be used for example to recognize images of paintings or to find similitude.

References


Figure 10. Examples on photograph.