MOTION MAP GENERATION FOR MAINTAINING THE TEMPORAL COHERENCE OF BRUSH STROKES

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Abstract: Painterly animation is a method that expresses images with a handpainted appearance from a video, and the most crucial element for it is the coherence between frames. A motion map generation is proposed in this paper as a resolution to the issue of maintaining the coherence in the brush strokes between the frames. A motion map refers to the range of motion calculated by their magnitudes and directions between the frames with the edge of the previous frame as a point of reference. The different methods of motion estimation used in this paper include the optical flow method and the block-based method, and the method that yielded the biggest PSNR using the motion information (the directions and magnitudes) acquired by various methods of motion estimation has been chosen as the final motion information to form a motion map. The created motion map determined the part of the frame that should be re-painted. In order to maintain the temporal coherence, the motion information was applied to only the strong edges that determine the directions of the brush strokes. Also, this paper sought to reduce the flickering phenomenon between the frames by using the multiple exposure method and the difference map created by the difference between images of the source and the canvas. Maintenance of the coherence in the direction of the brush strokes was also attempted by a local gradient interpolation in an attempt to maintain the structural coherence.

1 INTRODUCTION

The most crucial element in a painterly animation with an input of a video is to maintain the coherence in the brush strokes between frames. This paper proposes a motion map in order to resolve the issue of maintaining the coherence of brush strokes between frames in a painterly animation.

One of the basic information needed for the perception of the objects moving between frames (the foreground and the background) is the information of edges. The information of edges is a standard that distinguishes between the objects in a video and an essential element that visualize the motion. The motion map suggested in this paper is created using the information of edges as well as the motion information. In other words, a motion map refers to the range of a motion calculated by the magnitudes and directions of the motions of each object between frames with the edge of a previous frame as a point of reference, and the area where brush strokes should be newly created when passing on to the next frame. Our painting algorithm, applying the similar methods applied to the paint-on-glass animations, has sought to maintain the coherence of brush strokes between frames by applying new brush strokes by determining at the area of the motion map the area of the previous canvas where it should be re-painted to produce the images of the next frame.

Motion information can be acquired by the methods of motion estimation, such as the optical flow method(Horn and Schunck, 1981)(Lucas and Kanade, 1981) and the block-based method(Koga et al., 1981) (Tekalp, 1995). The motion information created by using the optical flow method accurately shows the direction of the motion, but it does not accurately depict the exact magnitude of the motion as a result of the noise and/or occlusion problem of the images(Tekalp, 1995). Although Litwinowicz(Litwinowicz, 1997) and Hertzmann(Hertzmann and Perlin, 2000) have produced motion information using the optical flow method, this paper sought to improve the accuracy of the motion information by choosing among the three methods of motion estimation(Horn and Schunck,

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1981)(Lucas and Kanade, 1981)(Koga et al., 1981) the method that yields the greatest PSNR. This paper also sought to maintain the coherence between frames by applying the motion information to strong edges that determine the direction of brush strokes among other elements.

The character of brush strokes is determined by such elements as the color, the direction, the size, and the shape. Most of the painterly rendering algorithms(Litwinowicz, 1997)(Hertzmann, 1998)(Hays and Essa, 2004) use a very simple form of brush strokes that have the same shapes and sizes among the characteristics of brush strokes. For such reasons, the resulting images convey a static, machine-like atmosphere, unlike the active and intense effects of the actual paintings. This paper, however, created brush strokes of diverse directions, sizes, and lengths using the linear and curvy shapes and local gradient interpolation, and applied them to the motion map in order to produce a painterly animation.

2 RELATED WORK

Litwinowicz and Hertzmann used the optical flow method for motion estimation in order to move the brush strokes from the previous frame to the current one(Litwinowicz, 1997)(Hertzmann and Perlin, 2000). This method, however, calculates the motion using only the intensity information between neighboring pixels, and thus, the occlusion problem between a foreground and a background and between a foreground and another foreground is neglected. This paper used both the optical flow method(Horn and Schunck, 1981)(Lucas and Kanade, 1981) and the block-based method(Koga et al., 1981) in order to resolve the problems associated with using twodimensional image, among the various methods of motion estimation chose the method with the biggest PSNR.

Hertzmann(Hertzmann and Perlin, 2000), in order to maintain the coherence of the brush strokes between frames, applied new brush strokes on the repainting part of the next frame by using the paintover method, similar to the paint-on-glass method, difference masking, and the motion data. His method, however, has two problems. First, because a video has noises and/or the occlusion problem, the motion information calculated between frames is not accurate. Hertzmann failed to resolve the problem of flickering by applying his motion data to every element such as the directions, locations, and shapes of the brush strokes(Hertzmann and Perlin, 2000). This paper sought to decrease the flickering phenomenon by applying the motion data only to the strong edges that determine the directions of the strokes and using the motion map elsewhere. Second, in a real paint-on-glass animation, the coherence between frames is maintained by using the canvas of the previous frame as the initial canvas for the next frame and by applying brush strokes only to where it should be re-painted. Hertzmann(Hertzmann and Perlin, 2000), however, warped the canvas of the previous frame using the inaccurate motion data, and used that warped canvas as the initial canvas for the next frame. Also, he calculated the difference masking not by using the images of the current source and the initial canvas, but by comparing the images of the previous sources with the images of the current sources. When using the difference masking calculated in such a way to paint the brush on the previously warped canvas, it may show much difference from the images of the current source and continue the flickering phenomenon onto the next frame. It is because the image with the most maintained coherence is an image of a source. This paper sought to maintain the coherence between frames by calculating the difference map between the image of the current source and the canvas onto which the motion map had been applied.

Hays redefined the characteristics of the brush strokes and produced brush strokes for each frame because a hole had appeared on the canvas due to the imperfect motion information and/or a phenomenon of partially erased characteristics of the brush strokes had appeared on the canvas(Hays and Essa, 2004). Hays method, however, also has disadvantages as it applies a process of decreasing the opacity by 10% for each frame in an attempt to avoid the flickering that emerge in the process of the redefinition of brush strokes. It is too dependent on opacity, in other words. The method also conveys a feeling of mere movement of brush strokes between frames by using only line brush strokes for the texture.

3 CREATION OF THE MOTION MAP

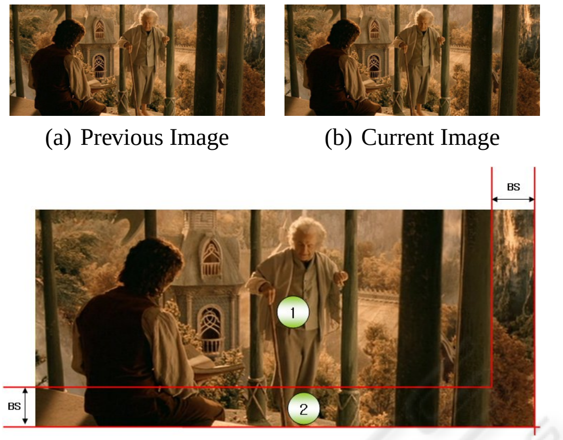
Motion estimation refers to the estimation of the vectors of the motion between the previous frame and the current frame. The method proposed by in this paper employed for motion estimation include: the method of finding the pixel with the minimum pixel-to-pixel variation among the flow vectors(Horn and Schunck, 1981); the method of motion estimation based on an assumption that the motion vector remains unchanged over a particular block of pixels(Lucas and Kanade, 1981); and the block-based method that, using the block mask, finds the pixels with the best-matching block of the same size(Koga et al., 1981). Based on the motion information(the directions and the magnitudes) gathered by using these methods, this paper chooses the method with the biggest PSNR.

A motion map is created by applying the method of perceiving an object in the channel that handle the forms and movements among other channels of handling the visual information, and this method of perception is reflected upon the edges of the moving object in focus. This paper creates a motion map by finding the range of the motion with the edge of the previous frame as a point of reference using the motion vectors found by the motion estimation. The newly created motion map determines where should be repainted in the next frame and maintains the coherence in brush strokes between the frames.

3.1 Motion Estimation

The HS(Horn and Schunck, 1981) and LK(Lucas and Kanade, 1981) optical flow method can apply motion estimation to the whole range of an image and the direction of the motion in its information is accurate, while the magnitude of the motion is not. On the contrary, the BM(Koga et al., 1981) method that looks for the pixels with the most correspondence to the previous frame as much as the size of a block mask per pixel provides the direction and the magnitude of the motion more accurate than those of the optical flow method, despite its disadvantage that the area 2 of Figure 1(C) cannot calculate the motion information. This paper chose the method with the biggest PSNR after calculating each motion vector by dividing the whole area into area 1 and area 2 just as in Figure 1. Table 1 is the result of the calculation of the peak signal to noise applying the optical flow method and the block-based method to each area. In case of calculating the motion vectors regarding the image in Figure 1(A–B), similar to the results shown in Table 1, after applying the motion information calculated by the BM method to Area 1 and the motion information calculated by the LK method to Area 2, the PSNR is calculated again based on the whole area(Area 1 + Area 2). Table 2 is the result of the calculation of the PSNRs from the optical flow method(Horn and Schunck, 1981)(Lucas and Kanade, 1981) and other method suggested in this paper. Equation 1–2 is the formula used to calculate the PSNR, and Element A is the warped image of the image of the previous source using the estimated motion information, and Element B is the image of the current source. This paper does not always choose the LK and BM methods as in Tables 1-2, but chooses the method with the biggest PSNR for each image. This paper also shortened the rendering time by calculating the motion information for all the images as a preprocessing step.

$$T = \sum_{i=1}^{SZ} (A_i - B_i)^2 \qquad (1)$$



(a) Previous Image (b) Current Image

(c) Dividing the whole area into area 1 and area 2 for Motion Estimation (BS : Block Size)

Figure 1: Images applied Motion Estimation and Area Segmentation for Motion Estimation Method.

$$PSNR(dB) = 10 * \log(\frac{65025.0}{T/SZ}) \qquad (2)$$

Table 1: 3 PSNR Values for each Area of Figure 1(C).

	PSNR(dB)(Area 1)	PSNR(dB)(Area 2)
HS	18.86403	19.70797
LK	20.90547	19.75762
BM	26.14414	

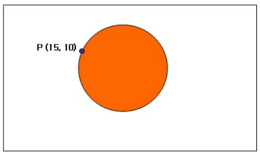
Table 2: 3 PSNR Values for the whole area of Figure 1(C).

	PSNR(dB) (Area 1 + Area 2)
HS	18.91518
LK	20.81920
OURS (Area 1:BM + Area 2:LK)	24.83612

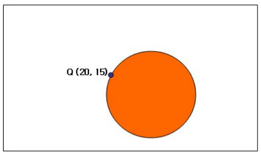
3.2 Motion Map

The edge information is one of the important elements for the visual perception of movements. This paper created a motion map based on the motion vectors and the edge information.

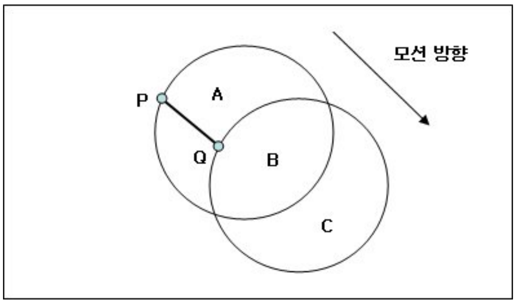
Figure 2 shows how a motion map is developed when a circle moves downward to the right. When a circle composed of Areas A and B of the previous frame moves to a circle composed of Areas B and C in the current frame, Area A transforms from a foreground into a background, Area B maintains its



(a) Previous Image



(b) Current Image



(c) Creation of Motion Map

Figure 2: Motion map is developed when a circle moves downward to the right (The point P and Q are a meeting point between frames, F(x,y,t)=(5 pixels, 5 pixels)).

foreground status despite the movements, and Area C transforms from a background to a foreground. This paper creates a motion map that includes Areas A and C by assuming the area of re-painting for the next frame as Areas A and C just as it is in the method of making the paint-on-glass animation. This method makes a motion map that includes the Areas A and C by drawing a line from Point P on the edge to Point Q when the Point P of the previous frame has moved to Point Q in the current frame. The motion map proposed in this paper has an advantage of easy creating using the edge and motion information without separating the foreground and the background. Figure 3 is a motion map using the method suggested by this paper.

Because the motion map is an area where the visual changes between frames are apparent, brush strokes of various sizes were applied in layers to the initial canvas of the current frame. The method to decide what size to use for the brush strokes when applying to a motion map in layers is similar to Hertzmanns method(Hertzmann, 1998) that forms one brush stroke in one grid. However, the brush strokes that go beyond the motion map can be removed by applying the brush strokes only when the proportion of the grid area and the area of the motion map exceeds a certain threshold. Figure 3(d) and Figure 3(e) show the brush strokes created using the motion map of Figure 3(C). As shown in Figure 3(D), applying brush strokes of various kinds to the next frame without regarding the size of the motion map area can cause much difference from the previous frame, bringing up much more flickering.

(a) Previous Image

(b) Current Image

(c) Motion Map

(d) applying brush strokes of various kinds to the next frame without regarding the size of the motion map area

(e) applying the brush strokes only when the proportion of the grid area and the area of the motion map exceeds a certain threshold(threshold : 50%)

Figure 3: Motion map and the canvas created using the motion map.

4 MOTION MAP BASED PAINTERLY ANIMATION

4.1 Direction

Painters usually draw a picture of an object following the edgy line of that object. Litwinowicz(Litwinowicz, 1997) proposed a local gradient interpolation. This method determines the directions of the brush strokes by interpolating the gradients of the surrounding pixels in case of a pixel with a gradient located in a certain area with a magnitude near 0. Because this method applies the interpolation to the area where the direction of the strokes is not certain, the direction of the brush strokes does not comply with the direction of the edges. In order to resolve this problem, this paper set strong edges that determine the direction, and made the direction of the surrounding pixels correspond to the direction set by the edges. This is similar to the Hays method(Hays and Essa, 2004), but while Hays(Hays and Essa, 2004) used the gradient interpolation of the whole area, this paper used the local gradient interpolation.

There are three steps to finding strong edges: first, calculating the magnitudes of the gradients of pixels on the edges using thinned images; second, organize the calculated sizes of the gradients in a descending order; third, choose the biggest gradient as a strong edge and remove the surrounding edges only when their difference from the strong edge in direction is smaller than a fixed threshold. Many strong edges can be found by repeating this process.

The local gradient interpolation method using the strong edges calculated the weight of the distances between the edges that are within R radius, which is N times the shortest distance with the location of P as a point of reference(Park and Yoon, 2004). The gradients in pixels were calculated by adding the gradients and weights of the strong edges on the radius R and dividing the number. Variable N is an experimental number, and the values between 1.5 and 2.5 were given to it.

$$Weight(i) = \left(\frac{MinDistance}{Distance(i)}\right)^b, i = 1, \ldots, M \tag{3}$$

Equation 3 is a gradient interpolation function in order to calculate the weighted gradient value at each pixel (x, y). The MinDistance of a element is the shortest distance from Point P to the strong edges on the radius R and is expressed as MD. The distance is the length between Point P and the strong edges on the radius R. M is the number of the strong edges on the radius R and b is a constant. Figure 4(c) explains Point P, MD and Radius R. This method is a variation of the method of interpolation used in morphing (Beier and Neely, 1992). Figure 4 shows the strong edges created and the interpolated gradient images using the method suggested in this paper.

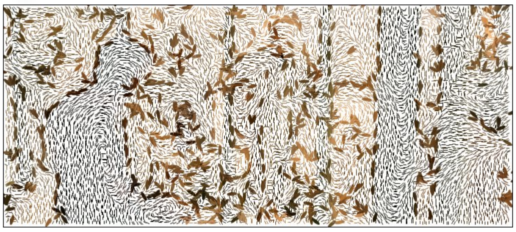
4.2 Color

Colors largely depend on the subjective motivations of the painters, and each painter has his own palette of distinctive colors. The Impressionists in particular were influenced by the flat form of the Japanese color prints. Considering this, this paper has attempted the method of flatizing the range of luminosity from 256 levels to 12 levels and the method of quantizing the colors (Deng et al., 1999b) (Deng et al., 1999a) (Park and Yoon, 2004). The painterly rendering in particular is handled by the units of random areas where the brush strokes are made, not by the pixel units, and thus, it is unnecessary to apply every color that forms an image of a source.

(a) Source Image

(b) Strong Edges Image

(c) Gradient Intepolation Using Strong Edges



(d) Gradient Interpolated Image

Figure 4: Strong Edge Image and Gradient Interpolated Image.

4.3 Shape and Size

Brush strokes have sizes of 4 to 32 pixels depending on the area of their application. The divided areas are painted using big brushes first, and then smaller brushes. The brush strokes are expressed in spline curves as well as the linear lines as a result of the application of the edge clipping. The control points of the spline curves are chosen in reference to the gradient interpolation of each pixel, and expanded upward and downward or left and right with the spline curve as a line of reference that follows the minimum of 2 and the maximum of 10 control points along the gradient from the starting point.

4.4 Maintenance of the Coherence Between Frames

Accurate motion information is necessary for the maintenance of coherence between frames. The existing methods of calculating motion information(Horn and Schunck, 1981)(Lucas and Kanade, 1981)(Koga et al., 1981) do not provide accurate motion information due to the noise or occlusion problem in the video(Tekalp, 1995). Those who studied the painterly animation earlier(Litwinowicz, 1997)(Hertzmann and Perlin, 2000)(Hays and Essa, 2004) cause the flickering phenomenon by applying the inaccurate motion information to every element of the brush strokes. The Hays method especially has a high dependency on opacity, conveying a feeling of mere movements of the brush strokes rather than a feeling of re-painting. This paper has applied motion information only to the strong edges that determined the element of direction of the brush strokes in an attempt to maintain coherence between frames. It is because the edge images found using random thresholds produce different results per frame, which may dislocate the strong edges. When the strong edges change their locations per frame, so does the direction of brush strokes. Figure 5 is an image resulting from moving the strong edges by applying the motion information in an attempt to maintain coherence of the directions of brush strokes.

Another method to maintain coherence between frames is to express the natural movements of the object by applying the multi-exposure method(Laybourne, 1998) as shown in Figure 6. This method expressed natural movements of the object by creating an in-between frame, blending Canvas 2 in a proportion of 7 (Canvas 1): 3(Canvas 4), and Canvas 3 in a proportion of 3 (Canvas 1):7(Canvas 2) after rendering only Canvases 1 and 4. This method is effective for the usage in a video with many movements, and has an advantage to alleviate the flickering phenomenon that can be caused by many differences in the colors of the brush strokes that are applied to the same location between frames.

The last method to maintain coherence between frames is to make a difference map between the canvas onto which a motion map has been applied and the image of the source and the re-paint it using a small brush. The area of effect of this method is Area B of Figure 2(c). This Area B had not appeared in the motion map, despite its motion, because its difference in intensity was not apparent from the surrounding pixels. Changes of each frame were probable in this area, so a difference map was made using the difference between the canvas of the applied brush strokes in the motion map and the image of the source, and Area B was re-painted with that map as a reference. Unlike Hertzmanns method(Hertzmann and Perlin, 2000) that makes a difference map between the warped image of the previous source and the image of the current source, the method applied in this paper made a difference map between the canvas where the area of the motion map had been re-painted and the image of the current source in an attempt to lessen the flickering phenomenon between frames. It is due to the fact that the image with the most coherence between frames is an image of a source, and the difference between a warped image of the previous source and the image of the current source is different from the difference between the previously warped canvas and the present canvas. Figure 7(G) is an image resulting from the area without the motion map, and the smallest brush was used to produce it.

5 RESULTS

Figure 5 is an image resulting from determining the directions of the brush strokes by applying motion information only to the strong edges between frames. This was an attempt to maintain coherence between frames by applying the motion information, which could be inaccurate due to the noise and the occlusion problem of the image, not to every element of the brush strokes (the direction, the location, the color, the form), but by applying it to only the direction between frames. Figure 6 is an image resulting from applying the multi-exposure method. Movements are naturally expressed by extracting the images of the source that have 8 frames per second from the video, rendering them, and blending the images between them. Figure 7 shows an image resulting from each step taken to maintain coherence between frames. Coherence is maintained by making a difference map between the image whose brush strokes are created and repainted by the motion map and the image of the source. Figure 8 is the images resulting from many scenes. You can find more images and videos created by the methods outlined in this paper on the website at : http://cglab.cse.cau.ac.kr/npr/index.html.

6 CONCLUSION AND FUTURE WORK

This paper has suggested the method of using a motion map in creating a painterly animation. The areas of repainting between frames are distinguished by the motion map made by the edge and motion information acquired from motion estimation. In an attempt to maintain coherence between frames, motion information was applied to only the strong edges that determined the directions of the brush strokes, and the multi-exposure method was used in order to express the natural movements of the object(Laybourne, 1998). Also, by making a difference map between the previous canvas and the current image of the source and applying the smallest brush strokes, the flickering phenomenon was also lessened.

Among the characteristics of brush strokes, the effects of color contrast, the brush texture expressed using rough brushes or knives, and the glazing effects need to be analyzed and simulated.

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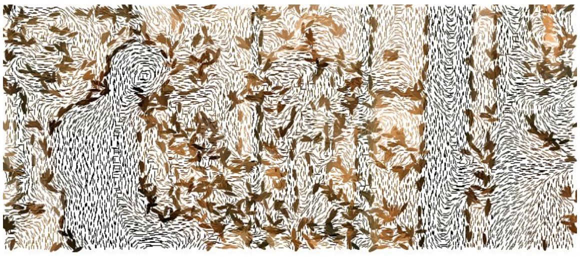
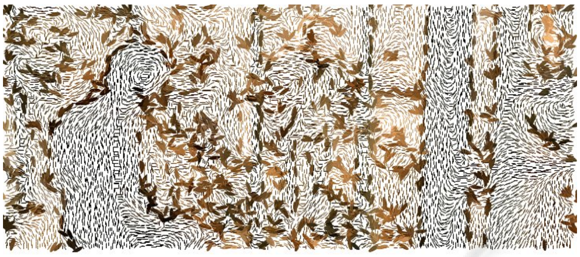
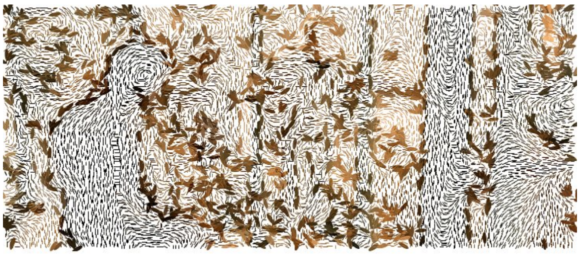


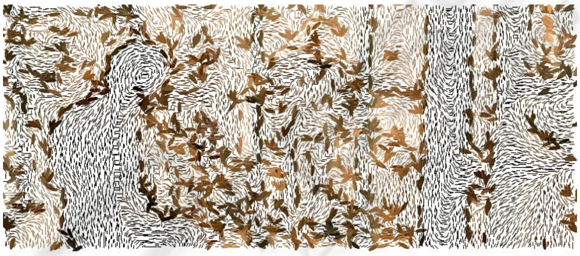
(a) 1st Strong Edges Image



(b) 4th Strong Edges Image



(c) 7th Strong Edges Image



(d) 10th Strong Edges Image

Figure 5: An image resulting from determining the directions of the brush strokes by applying motion information only to the strong edges between frames.

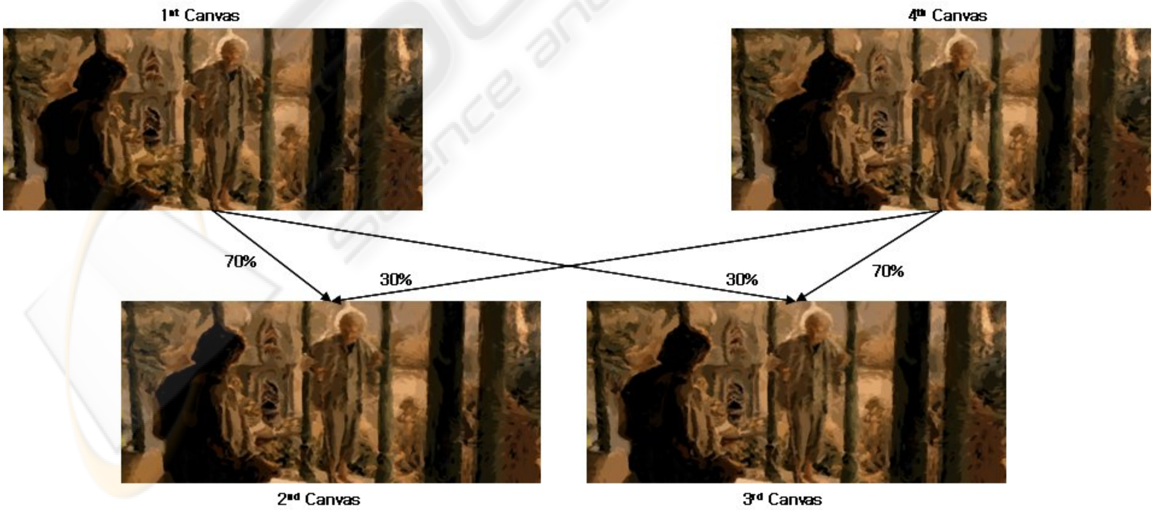


Figure 6: An image resulting from applying the multi-exposure method.

(a) 1st Source Image

(b) 1st Final Canvas and 4th Initial Canvas

(c) 4th Source Image

(d) Motion Map

(e) applying brush strokes of various kinds to the next frame with regarding the size of the motion map area

(f) (b)Image + (e)Image

(g) an Image applyied the smallest brush strokes by difference map between (f)canvas and (c)Image

(h) 4th Final Canvas ((f) Image + (g) Image)

Figure 7: An image resulting from each step taken to maintain coherence between frames.

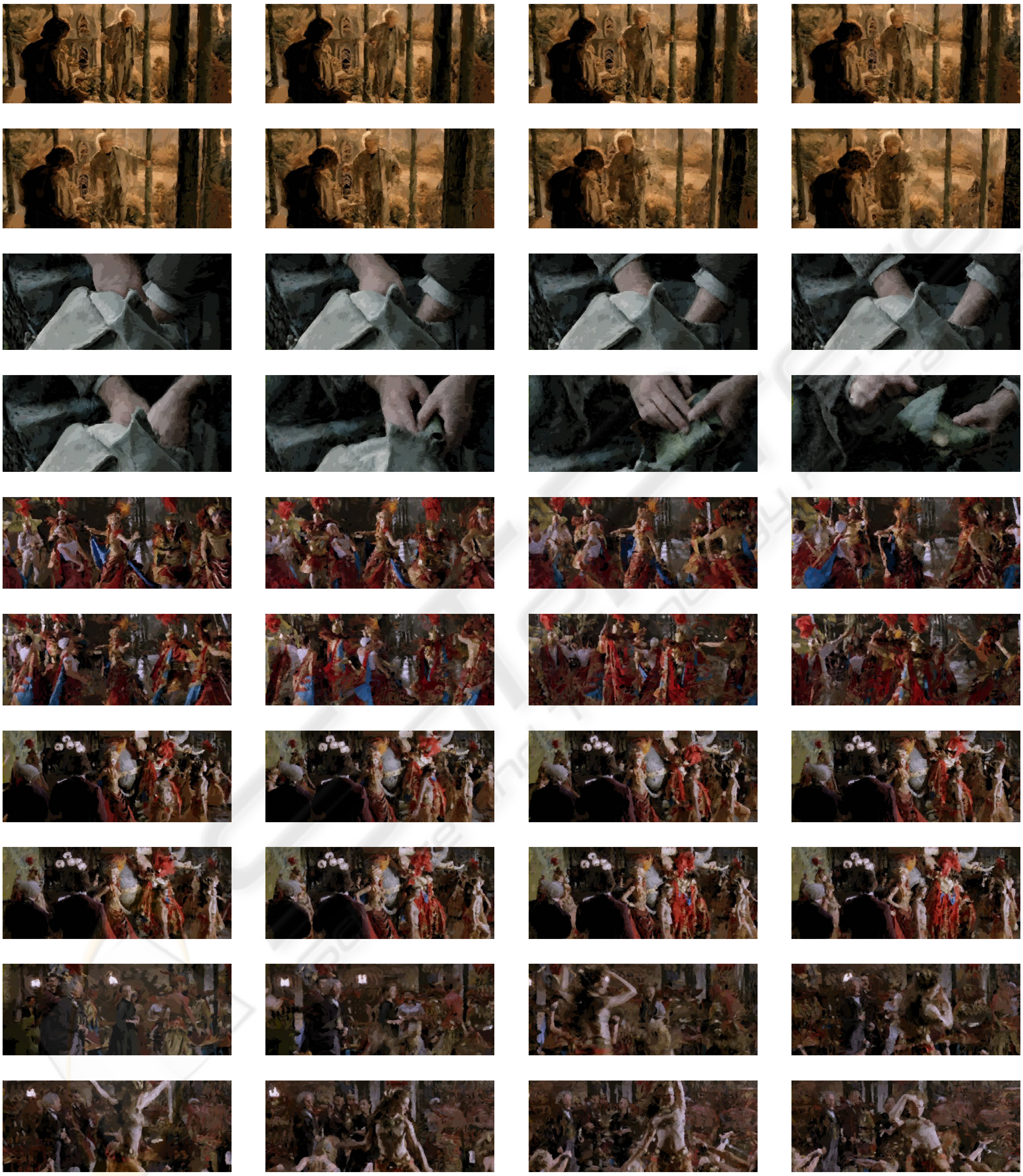


Figure 8: The images resulting from many scenes.