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Groen, F.C.A.; le Gue, R.; Smeulders, A.W.M.

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Application of digital image processing in Computer Aided Art.

Frans C.A. Groen

Pattern Recognition Group, Applied Physics Dept., Delft University of Technology
P.O. Box 5046, 2600 GA DELFT, THE NETHERLANDS

Raymond P. le Gué

HKG 333
Keizersgracht 333, 1016 EG AMSTERDAM, THE NETHERLANDS

Arnold W.M. Smeulders
Pattern Recognition Group, Applied Physics Dept., Delft University of Technology
P.O. Box 5046, 2600 GA DELFT, THE NETHERLANDS

Abstract

Digital Image Processing offers the possibility to realize novel special effects in Computer Aided Art. In this paper image processing methods are described to alter static scenes or to realize image transitions in animation. Transformations include conversion to dot patterns, line patterns and various enhancement and resolution effects. Examples are the production of a standart Dutch post stamp, contributions to an experimental television program presented by the Dutch broadcasting corporation and some poster designs.

Introduction

Having found employ in many sectors of society, we are on the verge of the use of the computer in the arts domain. In analogy to Computer Aided Instruction, Computer Aided Design and similar applications, Computer Aided Art (CAA) encompasses the use of the computer for artistic purposes. In this paper we present some examples in an important part of CAA: Artistic Image Manipulation.

From a practical point of view, artistic image manipulation may be devided in four categories which may have some overlap: these categories are

- a) Computer manipulation or generation of static scenes (cf. painting).
- b) Computer manipulation or generation of moving scenes (animation).
- c) Computer alteration of static scenes
- d) Computer alteration of moving scenes.

In the implementation of these four categories, the capabilities of a computer are indispensable. In fact, digital painting (category a) offers possibilities for artistic expression which are similar to classical paint work. Digital paintwork offers not only extra capabilities for trial and error over the use of brush and canvas, but may have essential artistic consequences when the possibilities of computer generation are fully exploited. Particularly the ability of mathematical control in the generation of the images, such as random markov processes. Commercially available systems might be used.

For the second category, (animation), the impact of the computer on the artistic expression is felt to have a larger potentiality. In animation, the computer mainly has been used to interpolate and compose hand-drawn static scenes. As is the case with the aforementioned category, (digital painting), the computer may contribute to new artistic techniques, by fully exploiting its mathematical capabilities. Moreover, the use of the computer is so much more efficient than the laborous manual practise that new possibilities for animation come within reach. In addition, using advanced computer graphics, new ways for animation are presently opened as is recently demonstrated in the picture named TRON.

In contrast to the two previously mentioned categories, computer capabilities are no longer optional for the third and fourth categories; but a condition sine qua non. These categories encompass the alteration of static and moving scenes. The basic difference with the two preceding categories is to be found in the fact that the artistic impression is embedded in the alteration of an image. The alteration may be static or dynamic. Apart from being static or dynamic, by feeding the output back into the input, a slowly altering scene may emerge, provided that the alteration is small.

Following the afore mentioned categorisation, it is quite clear that the different application fields of artistic image manipulation require different equipment. Three issues of the equipment are of special importance here: image resolution, computational speed, and the type of image operations.

Resolution

For Artistic Image Manipulation the image resolution should permit a very high image quality. For some applications it may suffice to perform computation at a moderately high resolution (e.g. 512x512 pixels) and display it on 4096x4096 pixels.

The resolution depends also upon the required output medium. When the output is a hard copy on paper or film, resolution may range up to 4096x4096 pixels over the output image. When the output is video a resolution of 830x620 pixels will do.

Speed

The speed requirements for applications in the first category (painting) are not so demanding because only one image is considered. Here, a simple minicomputer may suffice. For animation a considerable computing power usually is necessary to realize reasonable production time (e.g. a CRAY-1 was used for the production of TRON). In applications where the output is video (particularly category c and d) the objective is to realize image-processing at video-rate, which requires state-of-the-art computer capacity, even for simple applications. For more complex applications special hardware is needed. Other applications can only be achieved in animation. If one considers the fact that one second of program time, consists of 25 images, the speed in which one image is calculated and displayed is crucial, especially in the longer programs.

Types of image operations

From a technical point of view, apart from computer graphics, the following list of techniques may be applied in Artistic Image Manipulation.

- 1) combination of two or more images. This can be realized by adding, interpolation or mixings of only special parts (keying)
- 2) changes in the image position and size. Examples are : zoom, pan, tumble and spins
- 3) pseudo-colouring. Video-lookup tables give the possibility to pseudo-colour black- and white images, but also to change them dynamically, so that a changing palette arises. Special effects can be realized by a limited number of colours in the palette
- 4) transformation of a colour image into a dot image
- 5) transformation of a colour image into a line-image
- 6) generalized filtering of colour images

The operations 1), 2) and 3) are known as special digital effects and specialized systems are commercially available to realize these kind of operations real-time on video (Quantel¹, Ampex²). Operations in which the value of a pixel changes in relation to its neighbours like 4), 5) and 6) are available on digital image processing systems. However, these kind of systems are generally not well equipped to meet the requirements for professional video-processing. Video signals do not meet standard norms, only one frame-grabber is available instead of three, the output is RGB and must be PAL (SECAM or NTSC) coded.

Example

Recently, we have been involved in the development and production of image manipulation for artistic purposes. Projects concerned the standard Dutch post stamp, special effects for the programme: "Het eind = zoek" of the Dutch Broadcasting Corporation NOS and poster design.

In this paper we will discuss some of these projects which have been realised in category c: computer alteration of static scenes. This work has been performed with the Delft Image Processor system³, mainly in use for scientific and educational purposes. The system consists of a HP1000 minicomputer, a special purpose image processor (DIP-1) a flying spot scanner, a Grinnell display system (GMR270) and a Videoprint hardcopy device. The software is run under JIM, a command string interpreter, allowing simple access to existing image processing operations.

Dot pattern transformations

The following technique may be applied to transpose a grey tone image (or a colour image taken as three greytone images) into a dot pattern. In the display of the dot pattern care should be taken not to introduce an artificial texture/correlation pattern in the displayed image, not present in the original images. One of the most simple methods is the sigma-delta method⁴. Scanning the image from top left to bottom right, in the sigma-delta method a dot is placed, if the sum (sigma) of the past elements exceeds the maximal grey value. When a dot is placed, the sum is reduced by the maximum grey value, the remainder being the first contribution (delta) to the sum over the next elements. The remainder serves as a randomiser for the position of the dot to be displayed.

The original sigma-delta procedure has been adapted⁵ to two dimensions to reduce the occurrence of anisotropic dot patterns. But also for this technique, the "history" of delta is similar over subsequent lines, leading to regularities. In the next improvement, therefore, the direction of scan through the image is reversed at the end of each line. Odd lines are then scanned from left to right and even lines are scanned from right to left. As the history of the randomiser (delta) is different for every line, the regularity in the display is reduced further.

The standard Dutch post stamp of the artist P. Struycken was developed with the above mentioned technique. The problem was to realize a dot pattern image of the queen, with as few dots as possible, but still to guarantee a good resemblance at a normal position of view. At a closer look the image should fall apart into different dots. The dots should be placed in an irregular grid and stay a certain distance apart. Therefore, a program was realized to generate grids, in which the randomness was controllable ranging from a regular grid to a complete random grid.

In fig. 1a the original photograph is given and in fig. 1b a resulting post-stamp.

The dot pattern transformation can also be applied to realize a fading from one image into another. In fig. 2 an example of such a fading.

First a sequence of colour images was made fading from the first into the next image with an equal intensity, to result in about the same number of dots. Then the dot pattern transformation was applied subsequently on the red, green and blue image. Replay of these static, three color dots scenes give the impression of wriggling snowflakes moving from one image into the second. The elapsed time of the displayed sequence is approximately 5 sec.

Line-pattern transformations

Line-figures can be obtained by edge detection methods like gradient filters, Laplace filters or variance filters. These transformations offer the possibility to preserve some of the original image concept without the preservation of all details. These line patterns may be enhanced by clipping the transformed images.

Another way of obtaining a line-image is by a transformation of the image into iso-intensity lines.

Special effects can be obtained by mixing line-images with the original image for certain colours.

Fig. 3 shows an example of a sequence of iso-intensity transformations for a poster design. Again, this operations is very suited to perform online rendering moving line patterns. These operations perform best if the change in the underlying image is restricted and the image does not contain too much detail.

Generalized filtering

Soft focus is an example of the kind of operation which can be obtained with optical means. Well known are also the images in reduced resolution, in which a superpixel consists of a number of original pixels all with the same colour. This operation may be used very nicely to obtain a transition from one shot to another by reducing successively the resolution of the first shot cross the blockpattern and increase the resolution of the next shot again.

An excellent result can be obtained by Kuwahara filtering⁶ of an image. This operation renders smooth regions and sharp edges. The result resembles somewhat the Impressionist painting technique.

This non-linear filter smoothes an image without smoothing edges. This is realized by

investigating the variance over four regions of certain size around a pixel. It can be shown that under certain assumptions the region which does not contain an edge will have the smallest variance. The mean value of this region is computed and this forms the new pixel value. An example of a sequence of images, which are Kuwahara filtered with an increasing regions size is given in fig. 4.

Sharpening of the image can be obtained by linear filtering or by (non-linear) local contrast stretching. Repeatedly applied sharpening may be used to make transitions through a noise or maze image.

Exaggerated sharpening and filtering in general give an "exploding" impression when presented as a rapid sequence of images.

Conclusions

At this moment it is possible to apply digital image processing techniques for computer aided art. Problems arise in the field of digital special effects for video, because available image processing systems are not well suited for this type of application (one-frame grabber, no provisions for PAL or NTSC coding). There are image processing systems on the market which have the possibility to realize a number of operations at video-rate, however, they do not have even a standard video norm output signal. Future systems for this purpose should become available developed either by firms already in the video market or by makers of existing image processing equipment.

For some operations and some applications real-time use appears to be possible (pseudo-colour, resolution reduction, 3x3 convolution). For the more complicated operations real-time is at this moment not feasible leaving the possibility to operate in animation. The use of general purpose systems in animation give the possibility to generate completely new effects particularly important in the advertisement branch. The generation itself requires the close-cooperation between artist, producer, and image processing specialist.

Image processing of stills is much easier, because in this case there are no real-time constraints. The combination of image processing and computer graphics is advisable in this field.

The transformations that have been used were basically developed for image enhancement, and image recognition. With the advent of this new field of applications, the development of special techniques for this field is necessary and to be expected.

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Colour slides

Due to the high cost of colour printing only black and white photographs are given in the paper. However, black and white photographs cannot even partly reveal the effect which can be obtained in colour. Upon request a set of colour slides is available from the authors

Figure 1 a) Photograph of Queen Beatrix,

b) poststamp obtained with the dot pattern transformation

Figure 2 Example of a image transition with a dot pattern transformation

Figure 3 Example of a sequence of iso-intensity transformations

Figure 4 Example of a sequence of Kuwahara filtered images with an increasing region size