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Chroma-Key Effect by Optimizing Coarse and Fine Filter

Pallavi P. Kotgire, Dr. S. K. Shah

Pune University, Smt. Kashibai Navale college of Engineering,
Vadgaon Bk., Pune 411041, India
kotgirepallavi@gmail.com

Pune University, Smt. Kashibai Navale college of Engineering,
Vadgaon Bk., Pune 411041, India
san_shah@rediffmail.com

Abstract:*Keying has become a common image processing operation in TV and film production to separate elements from a background. Chroma keying is a robust and important technique for image processing or video which is widely used in magazine covers, cinema films, video game industries and also television programs such as live talk show, weather forecast. Chroma-key method is proposed in this paper using technique Coarse and fine filter in Real-time. Based on K-means clustering algorithm, the improved method is proposed namely Coarse and Fine Filter. Hardware Architecture for proposed method is implemented on Virtex 5 FPGA board. Later optimization of coarse and fine filter is done for reduction of resources utilization. Experimental results shows that proposed design can give better quality of composite image, requires less buffer size within very less time.*

Keywords:FPGA board, Chroma-key effect, K-means clustering, Coarse and Fine Filter, VLSI architecture.

1. Introduction

Video composition, or matting, is a key technologyin modern film and video production. Due to its good performance, cost savings by avoiding exterior filming and expensive scenery as well as its versatility to integrate real and computer-generated shots. Chroma key systems are a well-known video segmentation technique that combines a background image with video captures of real objects. This technique has largely replaced forward and rear projection for video segmentation since it shows lower complexity. Due to its versatility, chroma key has been applied not only in the film industry but also for gaming, education and augmented reality [1].

(a)

(b) (c)

Figure 1: Illustration of chroma-key effect a) foreground frame b) background frame c) composite frame

In a chroma key system, image segmentation is performed by removing a color from an image to reveal another image behind. A typical chroma key system is based on filming a real object in front of a monochromatic surface (usually blue or green) [7] This image provides one input into a chroma key processor. A second input is the desired background image (e.g. a computer-generated image). The chroma key processor combines both images distinguishing objects from the monochromatic surface and so they can be keyed to a different background by replacing the color key of the real image with the background image. After chroma processing, the composite image is broadcast or recorded as shown in fig 1 [2].

2. Literature Survey

In digital compositing technique “travelling matte” is used which is a complex and time-consuming process in the film industry. The drawback of the traditional travelling matteis that the cameras capturing the images cannot be synchronized. These shots had to be “locked-down”, so that thematted subject and the background could not shift theircamera perspective at all. Later on, computer-timed, motioncontrolcameras helped solving this problem, since both theforeground and background could be recorded with the samecamera moves using computerized motion controls. Later inthis technique, facts were exploited that in real-world scenesmost objects have a color whose green-color component issimilar in intensity to their blue color component [6].

In bluescreening, the background film is shot first, and themodel or actor is filmed carrying out their actions in front of a bluescreen [3]. As light added, ghostly image is created byplacing the foreground shot overlapping the background shot,with a blue-tinged background. The model or actor must beseparated from the background whichis to be removed andput into a specially-made “hole” in the background footage which is to be merged with the action made my actor ormodel. The background is exposed because the bluescreen shot is first rephotographed by a blue filter. A special film isused to create a black-and-white negative image blackbackground with a subject-shaped hole in the middle. This iscalled a ‘female matte’. The bluescreen shot is againrephotographed and this time a red-and-green filter is used. Tocreate a black silhouette on an unexposed (clear) backgroundonly the foreground image was cast on film. This is called a‘male matte’. The shot is rephotographed through the femalematte, and background image is then rephotographed throughthe male matte. These two images combined together createthe final effect which includes both male and female matte.An optical printer with two projectors, a ‘beam splitter’ and afilm camera is used to combine the images together one frameat a time. This part of the process is critical and should be verycarefully controlled to ensure the absence of ‘black lines’.

Beyond all these, there are some methods which extractthe object from foreground image. A common chroma keymethod to find the object to be masked from foregroundframe, in which the pixels belong to foreground object equal to 1, and ones belong to background object will be equalto 0. Therefore the masks of two colors, white andblack. The values that are equal to 1 are white, and ones thatare equal to 0 are black.After the mask has been obtained, the Chroma-key effectis performed on foreground and background frames with themask as below equation (1) [2]:

Composite frame = Frg.*mask + Brg.*(~mask) (1)

Where Frg and Brg are value of all pixels in theRGB color space of the foreground and background frame,respectively. Some methods that are performed the Chroma-key effectare referred and presented as follows:

2.1 Two Tone Checker Pattern

This type of method solves the problem in conventional chroma key techniques. If the foreground object is having same color with the background then it becomes transparent.The method utilizes the adjacency condition between thegeometrical information of the background grid line and twotoneregions of the background.

Kanade proposed a stereo machine for video-rate densedepth mapping that has a five-eye camera head handling thedistance range of 2 to 15m using 8mm lenses [4]. Kawakita et alproposed the axi-vision camera that has up-ramped and downrampedintensity-modulated lights with an ultrafast shutterattached to a CCD probe camera. These systems can obtainthe ranges from the camera to the objects in the capturedpicture and extract the objects from the images by using thegiven range information. However, since these systems consistof special devices, it is difficult for ordinary users to realizeimage segmentation by employing it. eg. Suppose the numberof foreground object pixels extracted manually was 340952,and this method extracted 338029 pixels as foreground objectpixels. This method failed to extract 3668 foreground pixels,and extracted 745 spurious pixels [5].

2.2 Fixed Key Method

This method is demonstrated by Thilina Sammera [9] andproposed a simple method to find out a mask of theforeground frame. However, by using this method theChroma-key process requires a key value first. To reach the*key* value, a manipulation scans overall values of the red (256values), green (256 values), blue (256 values) components ineach pixel of foreground frame. It takes too much time to do that, so author has built a GUI (Graphic User Interface) to facilitate the key value easily. This method has proposed asimple equation to find out the mask of foreground frame. If this method is used, finding a key value must beperformed first by scanning over 256x256x256=16.777.216values. It is hence very difficult and time consuming processin the finding key exactly, and hence this Fixed key method isnot picked out for hardware implementation.

2.3 Kmeans Clustering Method

A clustering method must be used to find the mask forChroma key method because key value based methods cannotprovide pleasing result due to the noise of the solid color inbackground object. The image is converted from *RGB* to*L*a*b** color space in the Matlab software, *a** and b*components are used to find the mask in foreground image, and then create composite frame. Chroma-key effect which isperformed by K-Means clustering has fairly good result.

Kardi Teknomo proposed a modified K-Means functionfor the Chroma-key effect which uses some iteration beforethe clustering has reached stability [8]. This method hasimproved the performance of clustering process. On the otherhand, the number of iterations required in each differentforeground frames is large, about eight or nine iterations in thetesting of foreground frames. Therefore, the buffer requiredfor the algorithm is very much large. In addition to this, thenumber of iterations is not constant for every differentforeground frames; thus, the size of buffer needed forhardware solution is not constant.

3. Proposed Chroma-Key Method

K-Means Clustering method requires very largebuffer, and it is a really hard constraint for real-time hardwareimplementation.

The main idea of this method is to improve the K-Meansfunction modified by Kardi Teknomo [2]. In the proposedmethod, the number of iterations is constant on coarse and finefilter processes, and the iteration on each frame is then replaced by each line of frame. Thus, the size of buffer willbe decreased considerably from a frame size to a line size of aframe in hardware implementation. For example, a frame with640x480 sizes, the size of buffer is of 640. In addition, the clustering done for all pixels of each line instead of all pixels of a frame will execute more accurately. A value used to set the admissible minimumdeviation between foreground and background object inforeground frame is applied to the coarse filter process asinput value for the setting two centroids differently in the firstiteration to help this filter perform better. After that the finefilter updates the values of two centroids and appliesclustering process based on Euclidean distances from thosecentroids. Architecture for the proposed method is implemented on the FPGA board.

The least important thing is that this method have advantages such as small buffer size, high accuracy in theclustering is to appropriate for implementing the Chroma-key effect by hardware in real-time.

The Coarse and Fine Filter algorithm is optimized to reduce the no of resources required. In Coarse and Fine filter method square difference is taken to mask the object, but it is optimized by taking absolute difference. Lastly it updates the values for both foreground as well as background object as before.

4. Hardware Architecture for Chroma-Key

This section consists of VLSI architecture that can performthe Chroma-key effect in real-time on a FPGA chip by usingCoarse and Fine Filter method.

4.1 Hardware Design

In the design process, finding a system which candemonstrate the implementation of the design in real-time isconcerned. One of the most important reasons for using thismodule is that its specification and Verilog code are availablefree for all users. It is thus easy to understand the activity ofall blocks of TV Box module as shown in Fig.3, and suitableto study and design a new module that can be integrated in thismodule to perform a special function or visional effect as the Chroma-key effect.

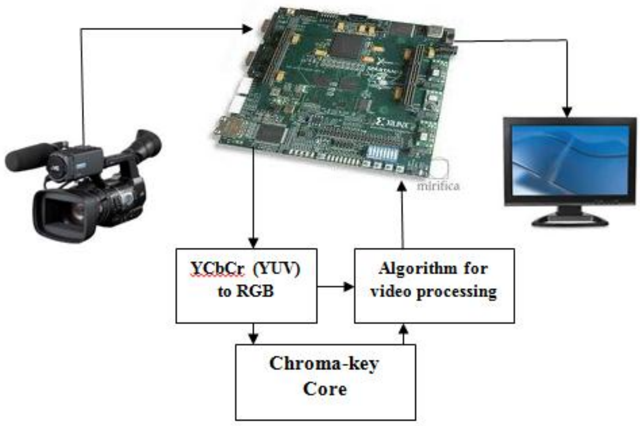

Figure 2: Proposed system for implementing Chroma-key effect in real-time.

Fig.2 Illustrates proposed system to perform the Chromakeyeffect on the board. The input video signal is retrievedfrom a camera [6], and then it is transferred to the board toperform the Chroma-key effect by using a Chroma-key chip,which contains the designed Chroma-key core embedded inthe ready TV Box module. Lastly, the output video signal is then displayed on a VGA(LCD/CRT) monitor.

4.1 Color Space

There is no function that converts directly RGB intoL*a*b* color space, this converting must be realized throughtwo the following steps:

- RGB into XYZ color space
- XYZ into L*a*b* color space

The equations to convert RGB into XYZ and XYZ intoL*a*b* color space are very complicated and difficult forhardware implementation. Therefore, the YCbCr color spaceis used to implement the Chroma-key effect in real-time [3,4].In addition to, inside the TV Box module, there are theYUV442 to 444 and YCbCr to RGB blocks to perform theconversion YUV 442 into YUV 444 (YCbCr) and YCbCr intoRGB color space, respectively [7].

4.2 Architecture of Chroma_key Core

In the TV Box module, Chroma-key chip is created byusing the Chroma_key core which is embedded in it. The Coarse and Fine Filter method is applied to thisdesign.The Block Diagram Chroma-key core consists of five blocks as shown in Fig.3.

1. Coarse filter block - This is one of two main blocks of thecore. Based on the background object that is green or blue, itperforms coarsely the clustering from the first two centroids,one is the Cb or Cr value of the first pixel of the foregroundframe, and another is the Cb or Cr value of the first pixel plusamount of *2**set deviation i. The sum1, count1, sum2, count2values created by this block will be transferred to theFine_filter block to calculate for new two centroids of the finefilter process in next iteration. In addition to, this block alsocreates signals to control the FIFOs of the other blocks such asrd fifo, wr fifo and reset fifo.

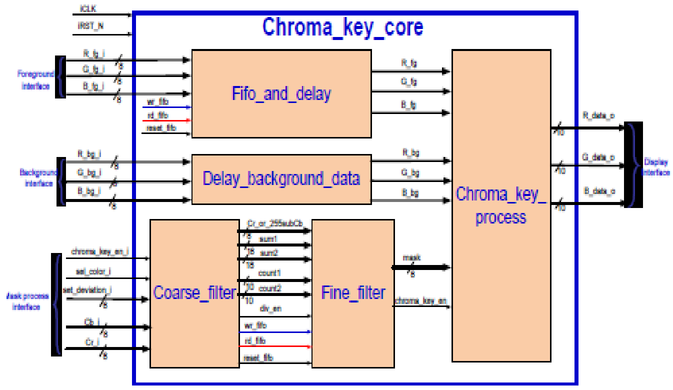

Figure 3: Block diagram of Chroma-key

2. Fine_filter block - This is another main block of the core.Depending on the sum1, sum2, count1, count2 values that getfrom the Coarse_filter block, and two centroids for the finefilter process will be calculated after the div_en signal isactive.The value of two centroids will obtain after the two cyclesthrough a divider inside this block. The clustering realizedwith new two centroids and the Cr_or_255subCb value of theCoarse_filter block will create a mask of the foregroundframe, and then the mask will be transferred to theChroma_key_process block to perform the Chroma-key effect.

3. Fifo_and_delay block - This block consists of three FIFOsto store red, green, blue components of each pixel in theforeground frame. The values that are read out from the FIFOswill be delayed one cycle to synchronize with the mask ofFine_filter block. The values after delay will be transferred tothe Chroma_key_process block to perform the Chroma-keyeffect.

4. Delay_background_datablock – As per name this blockperforms the delay on the background frame data which readfrom memory device to synchronize with the foregroundframe. To perform the Chroma-key effect the output of thisblock will be also transferred to the Chroma_key_processblock.

5. Chroma_key_processblock - Chroma-key process isperformed depending on the foreground frame data,background frame data and lastly the mask value.

5. Results and Discussions

The whole system is tested in Matlab software first. Two images are taken in .jpg or .jpegformat where it can be of variable width and height.As Coarse andFine Filter method is applied on two images to mask theobject which is having green background and merge with thebackground frame or overwrite the pixels with it, which gives composite image. After the Matlab simulation, thefunction is created which is being used in Simulink model.After the simulation of Simulink model it gives the sameresults as Matlab gives.Simulink is basically used to generatethe VHDL or Verilog code mostly in the hardware solution which is being implemented on FPGA board.

Now using Xilinx platform foreground frame is captured through camera modulein which green or blue colored backgroundenvironment is created while capturing image and background frame is stored in the BRAM. After complete process bit file is generated to download it on FPGA. Using Xilinx platform Coarse and Fine filter algorithm is optimized to make it easy for masking the object and merged the object with another image that is background frame which is stored in BRAM.Because of optimization DSP48, substractor, BRAM, registers, LUTS and IOs are reduced as shown in Table 1. As DSP48s are reduced, routing is also minimized and hence system can have better operating frequency. Time used for processing is also reduced i.e 0.47 secs. In hardware system the image is given to a FPGA board and a VGA monitor is used to display as shown in Fig 4. The result after the Chroma-key effect is implemented ablue or green cardboard is utilized to create the backgroundobject of the foreground frame, and a computer (laptop) is usedto download the Chroma-key program to the board.

(a) (b)

Figure 4: (a) Composite image formed using matlab (b) Composite image displayed on VGA Screen

A demonstration system has been set up as shown in Fig 5. The image is given to the FPGA board and chroma-key process is done on the hardware board itself.

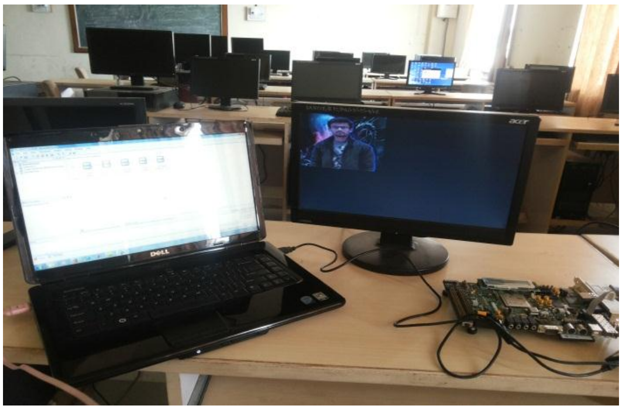

Figure 5: A demonstrated system for the Chroma-key effect

Table 1: Device Utilization

Slice logic Utilization	Coarse and Fine Filter method		Algorithm Optimization	
Slice registers	1653		234	
IO pins	426	90%	19	3%
LUTS	3086	9%	610	1%
Maximum frequency	40.33MHz		79.87MHz	
PLLs	1	25%		
DSP48	18	26%	3	1%
BRAM	88 of 1K	18%	88	66%

6. Conclusions

VLSIarchitecture is proposed by usingCoarse and Fine Filter method for chroma-key effect. This method is optimized to give better results in the form of resource utilization. Resources required for this improved method are reduced and increases time of processing.

The design is combined with the TVBox module, and implemented the Chroma-key effect in realtimeon the FPGA board.The results of this paper are initial achievements in order topropose a Chroma-key IP core, which can be applied for theprofessional studios or television systems in the future.

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Author Profile

Pallavi P. Kotgire was born in 1991. She has received B.Tech degree in Electronics and Telecommunication Engineering from SRT University, Nanded persuing her M.E degree in Electronics and Telecommunication with specialization in VLSI and Embedded System from Smt. Kashibai Navale College of Engineering, Vadgaon(bk), Pune in Pune university.

Dr. Sanjeevani K. Shah obtained her phD (E&TC) in 2012 from university of pune. Worked in Philips India Ltd. for three Years. Thereafter has twenty seven years of teaching experience. Presently working as Head of Post graduate department E&TC in STES's SKN College of engineering. Published books on Industrial Electronics, Communication, Applied electronics and has published 25 papers.