CONAHCYT

CONSEJO NACIONAL DE HUMANIDADES
CIENCIAS Y TECNOLOGÍAS

CIMAT

PROCESAMIENTO DE IMÁGENES USANDO CUDA

Dr. Francisco Javier Hernández López

CONAHCYT, CIMAT-Mérida

fcoj23@cimat.mx

LEER IMAGEN USANDO OPENCV

```
13   #include <opencv2/opencv.hpp>
14
15   int main(void){
16       cv::Mat Image;
17
18       //desde el disco duro
19       Image = cv::imread("../images/flowers8.png");
20
21       int nCols=Image.cols;
22       int nFils=Image.rows;
23
24       printf("\nLeyendo imagen de %d x %d pixeles...\n", nFils, nCols);
25
26       return(0);
27   }
```

Para compilar:
g++ `pkg-config --cflags opencv` LeerImagen.cpp -o LeerImagen `pkg-config --libs opencv`
g++ `pkg-config --cflags opencv4` LeerImagen.cpp -o LeerImagen `pkg-config --libs opencv4`

MODIFICAR IMAGEN A COLOR

```
4   /*CUDA*/
5   #include "cuda_runtime.h"
6
7   /*OpenCV*/
8   #include <opencv2/highgui/highgui.hpp>
9
10  #include "ModificarImagen.h"
11
12  int main(int argc, char **argv){
13      cudaSetDevice(0);
14      /*Host Variables*/
15      int imageW, imageH;       //Tamaño de la imagen
16      cv::Mat frame_Original;   //Imagen original
17      cv::Mat frame_Modified;   //Imagen modificada
18      /*Device Variables*/
19      uchar3 *Image_dev;
20
21      //cv::namedWindow("Original Frame",CV_WINDOW_AUTOSIZE);
22      //cv::namedWindow("Modified Frame",CV_WINDOW_AUTOSIZE);
23
24      /*Load Image*/
25      frame_Original = cv::imread("../images/Estacion_MR.jpg",1);
26
27      //cv::imshow("Original Frame", frame_Original);
```

MODIFICAR IMAGEN A COLOR (C1)

```
29      /*Size of Image*/
30      imageW=frame_Original.cols;
31      imageH=frame_Original.rows;
32      size_t size=3*imageW*imageH;
33
34      //Create Host memory
35      frame_Modified.create(imageH, imageW,CV_8UC(3));

37      /*Create device memory*/
38      cudaMalloc((void **)&Image_dev,size);

40      /*Copy Memory (Host-->Device)*/
41      cudaMemcpy(Image_dev,frame_Original.data,size,cudaMemcpyHostToDevice);

43      /*Define the size of the grid and thread blocks*/
44      dim3 threads(512,1,1);
45      int N=imageW * imageH;
46      dim3 grid(N/threads.x + (N%threads.x == 0 ? 0:1),1,1);
47      /*Launch the Kernel Function*/
48      CUDA_Modificar_Imagen(Image_dev,N,grid,threads);
```

MODIFICAR IMAGEN A COLOR (C2)

```
50      /*Copy Memory (Device-->Host)*/
51      cudaMemcpy(frame_Modified.data,Image_dev,size,cudaMemcpyDeviceToHost);

53      //cv::imshow("Modified Frame", frame_Modified);
54      //cv::waitKey(0);
55      //Guardar el resultado
56      cv::imwrite("../images/Estacion_MR_Modificada.jpg", frame_Modified);

58      /*Clean Memory*/
59      /*Host*/
60      //cv::destroyWindow("Original Frame");
61      //cv::destroyWindow("Modified Frame");
62      frame_Modified.release();
63
64      /*Device*/
65      cudaFree(Image_dev);
66
67      return(0);
68  }
```

MODIFICAR IMAGEN A COLOR (C3)

ModificarImagen.h* | ModificarImagen.cpp | ModificarImagen.cu

Miscellaneous Files | (Global Scope)

```
1
2  void CUDA_Modificar_Imagen(uchar3 *Image_dev,int N,dim3 grid,dim3 threads);
```

ModificarImagen.h* | ModificarImagen.cpp | ModificarImagen.cu*

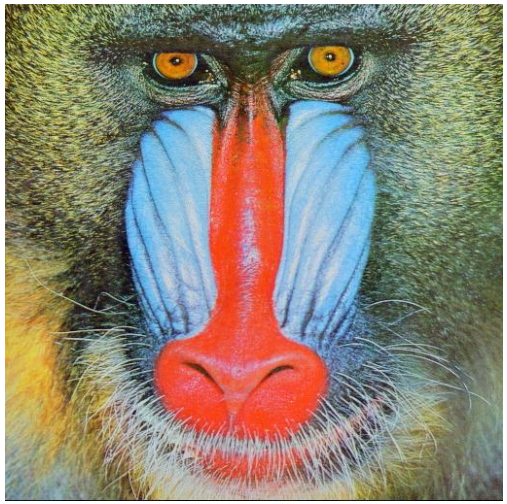
Miscellaneous Files | (Global Scope)

```
1
2  #include "ModificarImagen.h"
3  // Kernel Function which is executed in the Device.
4  __global__ void Modificar_Imagen(uchar3 *Imag,int N)
5  {
6      int idx = blockIdx.x * blockDim.x + threadIdx.x;
7
8      if (idx<N){
9          if((Imag[idx].x+Imag[idx].y+Imag[idx].z)/3 > 250){
10             Imag[idx].x=255;  //B
11             Imag[idx].y=0;    //G
12             Imag[idx].z=0;    //R
13         }
14     }
15 }
16 void CUDA_Modificar_Imagen(uchar3 *Image_dev,int N,dim3 grid,dim3 threads){
17     Modificar_Imagen<<<grid,threads>>> (Image_dev,N);
18 }
```

Para compilar:

nvcc `pkg-config --cflags opencv4` ModificarImagen.cu ModificarImagen.cpp -o ModificarImagen `pkg-config --libs opencv4`

COMPOSICIÓN DE IMÁGENES

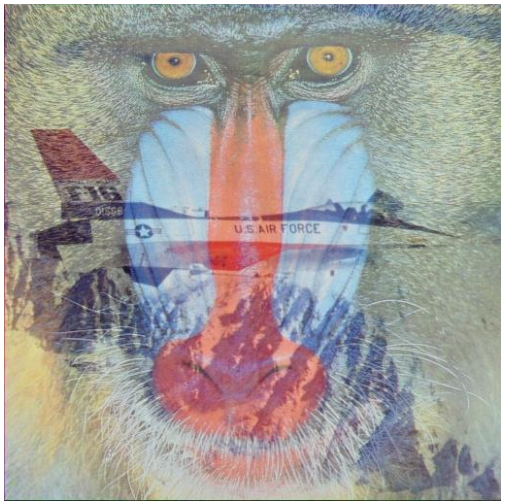


αI_1

+

$(1-\alpha)I_2$

=



O **con** $\alpha = 0.5$

COMPOSICIÓN DE IMÁGENES (C1)

```
3   #include <stdio.h>
4   /*CUDA*/
5   #include <cuda_runtime.h>
6   /*OpenCV*/
7   #include <opencv2/highgui/highgui.hpp>
8   #include "ImageComposition.h"
9
10  //alpha parameter
11  int alpha_int=75;
12  float alpha= (float)alpha_int / 100; //[0,1]
13  void Change_alpha(int,void *){
14      alpha=(float)alpha_int/100;
15  }
16
17  int main(int argc, char **argv){
18      cudaSetDevice(0);
19      /*Host Variables*/
20      int imageW, imageH;         //Size of Image
21      cv::Mat frame1_Original;    //Original Image
22      cv::Mat frame2_Original;    //Original Image
23      cv::Mat frame_Composed;
```

COMPOSICIÓN DE IMÁGENES (C2)

```
25      /*Device Variables*/
26      uchar3 *Image1_dev,*Image2_dev,*ComposedImage_dev;
27
28      /*cv::namedWindow("Original Frame1",CV_WINDOW_AUTOSIZE);
29      cv::namedWindow("Original Frame2",CV_WINDOW_AUTOSIZE);
30      cv::namedWindow("Composed Frame",CV_WINDOW_AUTOSIZE);
31      cv::createTrackbar("alpha", "Composed Frame",&alpha_int,100,Change_alpha,0);*/
32
33      char name_imag[500];
34      /*Load Image*/
35      sprintf(name_imag,"../images/baboon.jpg");
36      frame1_Original = cv::imread(name_imag,1);
37
38      sprintf(name_imag,"../images/airplane.jpg");
39      frame2_Original = cv::imread(name_imag,1);
40
41      /*Size of Image*/
42      imageW=frame1_Original.cols;
43      imageH=frame1_Original.rows;
44      size_t size=imageW*imageH*sizeof(uchar3);
```

COMPOSICIÓN DE IMÁGENES (C3)

```
46      /*Create host memory*/
47      frame_Composed.create(imageH,imageW,CV_8UC(3));
48
49      /*Create device memory*/
50      cudaMalloc((void **)&Image1_dev,size);
51      cudaMalloc((void **)&Image2_dev,size);
52      cudaMalloc((void **)&ComposedImage_dev,size);
53
54      /*Copy Memory (Host-->Device)*/
55      cudaMemcpy(Image1_dev,frame1_Original.data,size,/*Complete*/);
56      cudaMemcpy(Image2_dev,frame2_Original.data,size,/*Complete*/);

58      /*Define the size of the grid and thread blocks*/
59      dim3 threads(/*Complete*/,1,1);
60      int N=imageW * imageH;
61      dim3 grid(N/threads.x + (N%threads.x == 0 ? 0:1),1,1);
62
63      /*cv::imshow("Original Frame1",frame1_Original);
64      cv::imshow("Original Frame2",frame2_Original);*/
```

COMPOSICIÓN DE IMÁGENES (C4)

```
66      //while(1){
67          /*Launch the Kernel Function*/
68          CUDA_Compose_Images(ComposedImage_dev,Image1_dev,Image2_dev,alpha,N,grid,threads);
69
70          /*Copy Memory (Device-->Host)*/
71          cudaMemcpy(frame_Composed.data,ComposedImage_dev,size,/*Complete*/);
72
73          //cv::imshow("Composed Frame",frame_Composed);
74
75      /*  char key=cvWaitKey(2);
76          if(key==27) {
77              break;
78          }
79      }*/
81      //Save the result
82      cv::imwrite("../results/Compose_babon_airplane.jpg", frame_Composed);
83
84      /*Clean Memory*/
85      /*Host*/
86      /*cv::destroyAllWindows();*/
87      frame_Composed.release();
88      /*Device*/
89      cudaFree(Image1_dev);
90      cudaFree(Image2_dev);
91      cudaFree(ComposedImage_dev);
92
93      return(0);
94  }
```

COMPOSICIÓN DE IMÁGENES (C5)

ImageComposition.h* | ImageComposition.cpp | ImageComposition.cu

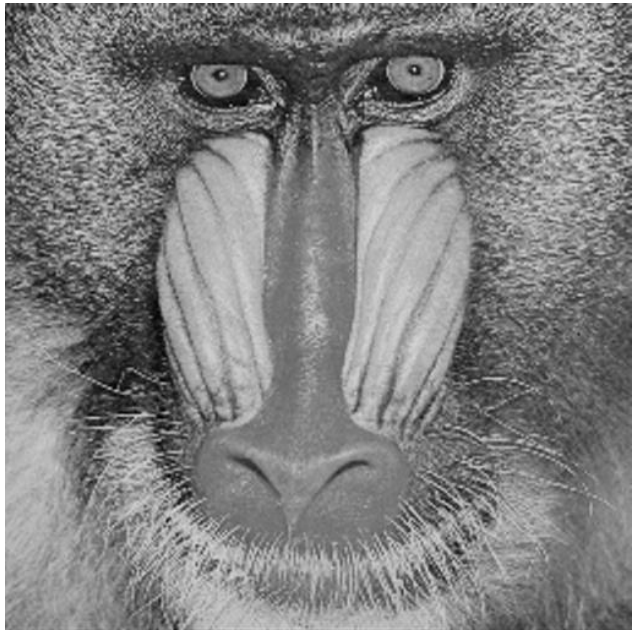
Miscellaneous Files | (Global Scope)

```
1
2   void CUDA_Compose_Images(uchar3 *ComposedImage_dev,uchar3 *Image1_dev,uchar3 *Image2_dev,
3                            float alpha,int N,dim3 grid,dim3 threads);
```

ImageComposition.h | ImageComposition.cpp | ImageComposition.cu

```
1   #include "ImageComposition.h"
2
3   __global__ void Compose_Images(uchar3 *ComposedImage_dev,uchar3 *Image1_dev,uchar3 *Image2_dev,
4                                  float alpha,int N){
5       int idx = blockIdx.x * blockDim.x + threadIdx.x;
6       if (/*Complete*/){
7           ComposedImage_dev[idx].x=alpha*/*Complete*/+(1-alpha)*/*Complete*/;
8           ComposedImage_dev[idx].y=alpha*/*Complete*/+(1-alpha)*/*Complete*/;
9           ComposedImage_dev[idx].z=alpha*/*Complete*/+(1-alpha)*/*Complete*/;
10      }
11  }
12
13  void CUDA_Compose_Images(uchar3 *ComposedImage_dev,uchar3 *Image1_dev,uchar3 *Image2_dev,
14                           float alpha,int N,dim3 grid,dim3 threads){
15      Compose_Images<<</*Complete*/>>>(ComposedImage_dev,Image1_dev,Image2_dev,alpha,N);
16  }
```

APLICAR FILTROS A UNA IMAGEN



I_Original

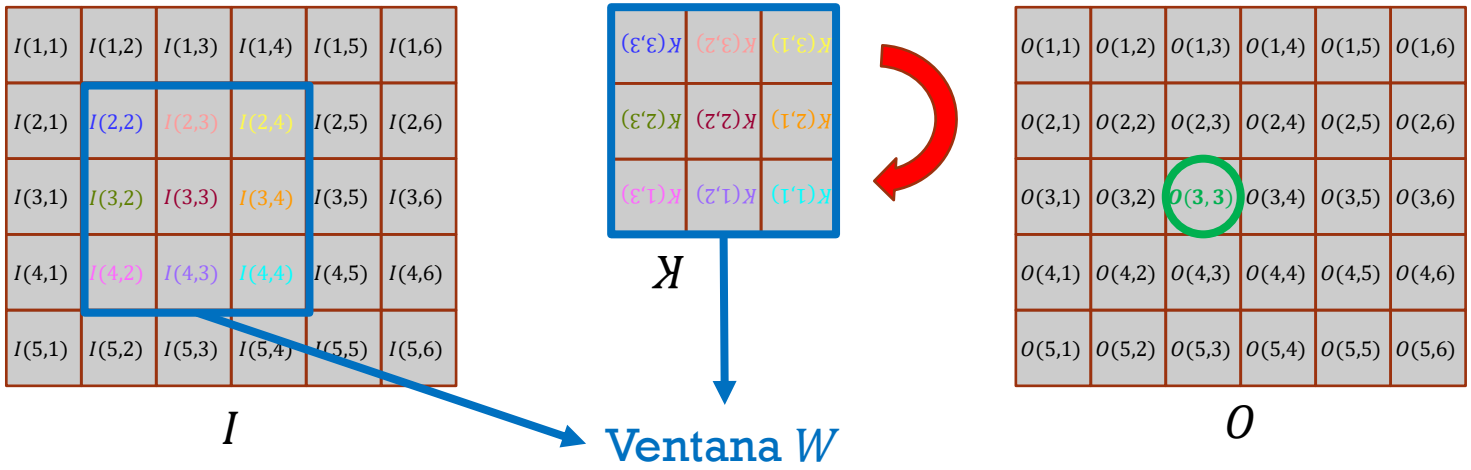
$$\otimes \frac{1}{49}\begin{pmatrix} 1 & \dots & 1 \\ \vdots & \ddots & \vdots \\ 1 & \dots & 1 \end{pmatrix}_{7\times 7} =$$

Kernel de convolución
o correlación

I_Filtrada

CONVOLUCIÓN

correlación con kernel girado



$$O(3,3) = I(4,4) * K(1,1) + I(4,3) * K(1,2) + I(4,2) * K(1,3) + I(3,4) * K(2,1) + I(3,3) * K(2,2) + I(3,2) * K(2,3) + I(2,4) * K(3,1) + I(2,3) * K(3,2) + I(2,2) * K(3,3)$$

filter2D

Convolves an image with the kernel.

C++: void `filter2D`(InputArray **src**, OutputArray **dst**, int **ddepth**, InputArray **kernel**, Point **anchor**=Point(-1,-1), double **delta**=0, int **borderType**=BORDER_DEFAULT)

OpenCV: https://docs.opencv.org/3.4.1/d4/d86/group__imgproc__filter.html

FILTROS: PROMEDIO, GAUSSIANO Y LAPLACIANO

```
3   #include <stdio.h>
4   /*CUDA*/
5   #include <cuda_runtime.h>
6   /*OpenCV*/
7   #include <opencv2/opencv.hpp>
8
9   #include "ImageFilters.h"
10
11  //División techo.
12  int iDivUp(int a, int b){
13      return ((a % b) != 0) ?
14             (a / b + 1) : (a / b);
15  }
16
17  //PARAMETERS
18  #define BLOCKDIM_X 16
19  #define BLOCKDIM_Y 16
20
21  int main(int argc, char **argv){
22      /*Host Variables*/
23      int imageW, imageH;      //Size of Image
24      cv::Mat I_Original;      //Original Image
25      cv::Mat I_Filtrada;      //Para guardar el resultado
26      cv::Mat I_Filtrada_C1F; //Imagen de 1 Canal en Float
```

$$K_{Promedio} = \frac{1}{tW \times tW}\begin{pmatrix} 1 & \dots & 1 \\ \vdots & \ddots & \vdots \\ 1 & \dots & 1 \end{pmatrix}_{tW \times tW}$$

$$K_{Gaussiano} = \frac{1}{16}\begin{pmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{pmatrix}$$

$$K_{Laplaciano} = \begin{pmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

FILTROS: PROMEDIO, GAUSSIANO Y LAPLACIANO (C1)

```
27      /*Device Variables*/
28      unsigned char *I_Original_dev;
29      unsigned char *I_Filtrada_dev;
30      float *I_Filtrada_C1F_dev;
31
32      char name_imag[500];
33      /*Load Image*/
34      sprintf(name_imag,/*Completar*/);
35      I_Original = cv::imread(name_imag,0);
36
37      /*Size of Image*/
38      imageW=I_Original.cols;
39      imageH=I_Original.rows;
40      size_t size=imageW*imageH*sizeof(unsigned char);
41      size_t sizef=imageW*imageH*sizeof(float);
42
43      I_Filtrada.create(imageH, imageW, CV_8UC(1));
44      I_Filtrada_C1F.create(imageH, imageW, CV_32FC(1));
46      /*Create device memory*/
47      cudaMalloc((void **)&I_Original_dev, size);
48      cudaMalloc((void **)&I_Filtrada_dev,size);
49      cudaMalloc((void **)&I_Filtrada_C1F_dev,sizef);
50      cudaMemset(I_Filtrada_dev, 0, size);//Inicializamos en cero
51      cudaMemset(I_Filtrada_C1F_dev, 0, size);
```

FILTROS: PROMEDIO, GAUSSIANO Y LAPLACIANO (C2)

```
54      /*Copy Memory (Host-->Device)*/
55      cudaMemcpy(I_Original_dev,I_Original.data,size,/*Completar*/);
56
57      /*Define the size of the grid and thread blocks*/
58      dim3 threads(/*Completar*/);
59      dim3 grid(iDivUp(imageW, /*Completar*/), iDivUp(imageH, /*Completar*/),1);
61      /*Launch the Kernel Function*/
62      //Mean Filter
63      CUDA_MeanFilter(I_Filtrada_dev, I_Original_dev,imageW,imageH,grid,threads);
64      //CUDA_GaussianFilter(I_Filtrada_dev, I_Original_dev,imageW,imageH,grid,threads);
65      //CUDA_LaplacianFilter(I_Filtrada_C1F_dev,I_Original_dev,imageW,imageH,grid,threads);
67      /*Copy Memory (Device-->Host)*/
68      cudaMemcpy(I_Filtrada.data, I_Filtrada_dev, size, /*Completar*/);
69      //cudaMemcpy(I_Filtrada_C1F.data, I_Filtrada_C1F_dev,sizef,/*Completar*/);
71      cv::imshow("Imagen Original", I_Original);
72      cv::imshow("Imagen Filtrada", I_Filtrada);
73      /*cv::normalize(I_Filtrada_C1F, I_Filtrada_C1F, 1, 0, CV_MINMAX);
74      cv::imshow("Imagen Filtrada", I_Filtrada_C1F);*/
75      cv::waitKey(0);
85      cv::imwrite("../../../images/Baboon_512_MeanFilter.png",I_Filtrada);
86      //cv::imwrite("../../../images/Baboon_512_GaussianFilter.png", I_Filtrada);
87      /*cv::normalize(I_Filtrada_C1F, I_Filtrada_C1F, 255, 0, cv::NORM_MINMAX);
88      cv::imwrite("../../../images/Baboon_512_LaplacianFilter.png", I_Filtrada_C1F);
```

FILTROS: PROMEDIO, GAUSSIANO Y LAPLACIANO (C3)

```
82      /*Clean Memory*/
83      /*Host*/
84      I_Filtrada.release();
85      I_Filtrada_C1F.release();
86      //cv::destroyAllWindows();
87      /*Device*/
88      cudaFree(I_Original_dev);
89      cudaFree(I_Filtrada_dev);
90      cudaFree(I_Filtrada_C1F_dev);
91
92      return(0);
93  }
```

ImageFilters.cu* | ImageFilters.cpp*

imageFilters | (Global Scope)

```
1
2    #include "ImageFilters.h"
3
4   /*__constant__ float MeanKernel[3][3] = {{1,1,1},
5                                          {1,1,1},
6                                          {1,1,1}};*/
7
8    __constant__ float GaussianKernel[3][3] = {/*Completar*/};
9
10   __constant__ float LaplacianKernel[3][3] = {/*Completar*/};
```

FILTRO PROMEDIO

```
12  /*Image Filters*/
13  __global__ void MeanFilter_kernel(unsigned char *Dst_dev, unsigned char *Src_dev,
14                                    int imageW,int imageH){
15
16      const int ix = blockDim.x * blockIdx.x + threadIdx.x;
17      const int iy = blockDim.y * blockIdx.y + threadIdx.y;
18
19      int rW = 3;//radio de la ventana
20      int tW = rW * 2+1;
21      if(ix>=rW && ix < imageW-rW && iy>=rW && iy < imageH-rW){//Dejamos un margen de tamaño rW
22          float sum=0;
23          int idx;
24          for(int k_i=0;k_i<tW;k_i++){//Para recorrer el Kernel en cada pixel (iy,ix)
25              idx = (iy + (k_i - rW))*imageW + ix;
26              for(int k_j=0;k_j<tW;k_j++){
27                  sum+=(float)Src_dev[idx + (k_j - rW)];
28                  /*sum+=(float)Src_dev[idx + (k_j - rW)]*MeanKernel[k_i][k_j];*/
29              }
30          }
31          idx = iy*imageW + ix;
32          Dst_dev[idx]=(unsigned char)(sum/(tW*tW));
33      }
34  }
```

FILTRO GAUSSIANO

```
33  __global__ void GaussianFilter_kernel(unsigned char *Dst_dev, unsigned char *Src_dev,
34                                        int imageW, int imageH) {
35
36      const int ix = blockDim.x * blockIdx.x + threadIdx.x;
37      const int iy = blockDim.y * blockIdx.y + threadIdx.y;
38
39      if (ix >0 && ix < imageW - 1 && iy >0 && iy < imageH - 1) {//Dejamos un margen de tamaño 1
40          float sum = 0;
41          int idx;
42          for (int k_i = 0; k_i<3; k_i++) {//Para recorrer el Kernel en cada pixel (iy,ix)
43              idx = (iy + (k_i - 1))*imageW + ix;
44              for (int k_j = 0; k_j<3; k_j++) {
45                  sum += (float)Src_dev[idx + (k_j - 1)] * /*Completar*/;
46              }
47          }
48          idx = iy*imageW + ix;
49          Dst_dev[idx] = (unsigned char)(sum / 16);
50      }
51  }
```

FILTRO LAPLACIANO

```
56  __global__ void LaplacianFilter_kernel(float *Dst_dev, unsigned char *Src_dev,
57                                         int imageW, int imageH){
58
59      const int ix = blockDim.x * blockIdx.x + threadIdx.x;
60      const int iy = blockDim.y * blockIdx.y + threadIdx.y;
61
62      if (ix >0 && ix < imageW - 1 && iy >0 && iy < imageH - 1) {//Dejamos un margen de tamaño 1
63          float sum = 0;
64          int idx;
65
66          /*Completar*/
67
68          idx = iy*imageW + ix;
69          Dst_dev[idx] = sum;
70      }
71  }
```

FILTROS: PROMEDIO, GAUSSIANO Y LAPLACIANO (C4)

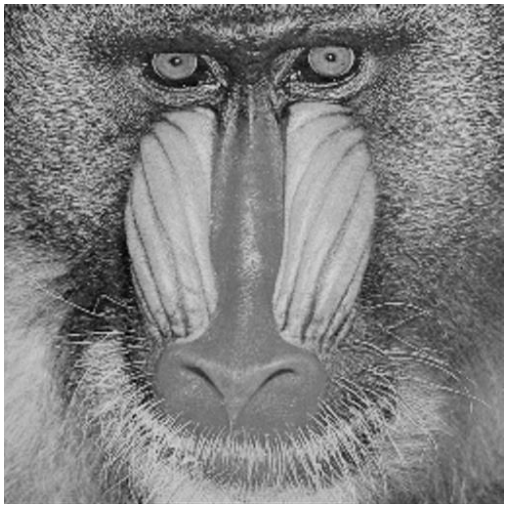
ImageFilters.h | ImageFilters.cu* | ImageFilters.cpp

```
73  void CUDA_MeanFilter(unsigned char *Dst_dev, unsigned char *Src_dev,int imageW,int imageH,
74                       dim3 grid,dim3 threads){
75      MeanFilter_kernel/*Completar*/(Dst_dev,Src_dev,imageW,imageH);
76  }
77
78  void CUDA_GaussianFilter(unsigned char *Dst_dev, unsigned char *Src_dev, int imageW, int imageH,
79                           dim3 grid, dim3 threads) {
80      GaussianFilter_kernel/*Completar*/(Dst_dev, Src_dev, imageW, imageH);
81  }
82
83  void CUDA_LaplacianFilter(float *Dst_dev, unsigned char *Src_dev,int imageW,int imageH,
84                            dim3 grid,dim3 threads){
85      LaplacianFilter_kernel/*Completar*/(Dst_dev, Src_dev,imageW,imageH);
86  }
```

ImageFilters.h* | ImageFilters.cu* | ImageFilters.cpp

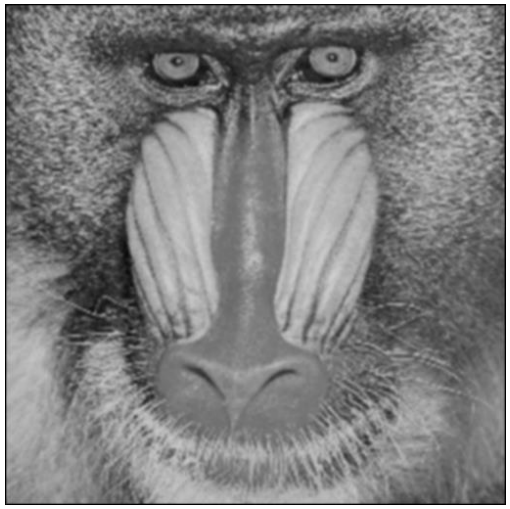
```
4   void CUDA_MeanFilter(unsigned char *Dst_dev,unsigned char *Src_dev,int imageW,int imageH,
5                        dim3 grid,dim3 threads);
6
7   void CUDA_GaussianFilter(unsigned char *Dst_dev, unsigned char *Src_dev, int imageW, int imageH,
8                            dim3 grid, dim3 threads);
9
10  void CUDA_LaplacianFilter(float *Dst_dev, unsigned char *Src_dev, int imageW, int imageH,
11                            dim3 grid, dim3 threads);
```

RESULTADOS

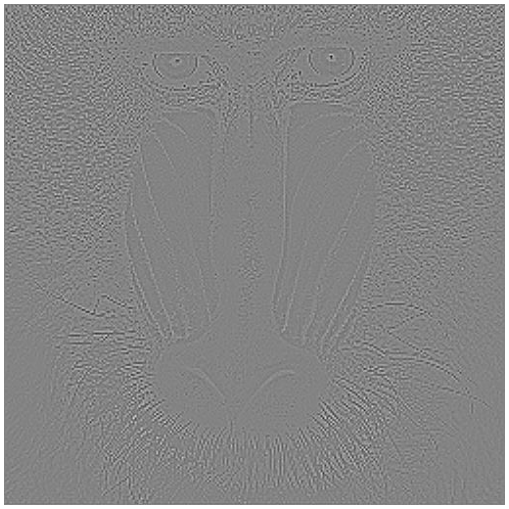


I_Original

I_Filtrada, $K_{Promedio}$



I_Filtrada, $K_{Gaussiano}$



I_Filtrada, $K_{Laplaciano}$

GRACIAS POR SU ATENCIÓN

Francisco J. Hernandez-Lopez

fcoj23@cimat.mx

WebPage:

www.cimat.mx/~fcoj23