ECE 6310 Introduction to Computer Vision
Lab #1 – Convolution, separable filters, sliding windows

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1 Assignment

In this project each student must implement three versions of a 7x7 mean filter. The first version should use basic 2D convolution. The second version should use separable filters (1x7 and 7x1). The third version should use separable filters and a sliding window.

All three versions of the filter should produce the exact same output. This must be verified by comparing the images using "diff" or a similar program and showing the method used and result. Each version of the filter should be timed, and the typical amount of time reported (for example, the average amount of time over ten runs).

Each version of the filter should be timed, and the typical amount of time reported (for example, the average amount of time over ten runs).

You must write a brief report that includes the code for each filter. The report should summarize and compare the amounts of time each version of the filter takes.

C-code for smoothing a 512 x 512 image is posted at the class website. The program contains code demonstrating a 3x3 mean filter using basic 2D convolution, and how to time a piece of the program. You can use this code to derive a solution to this lab.

The report is due date is given at the web site. Reports will be collected in class.

2 Images

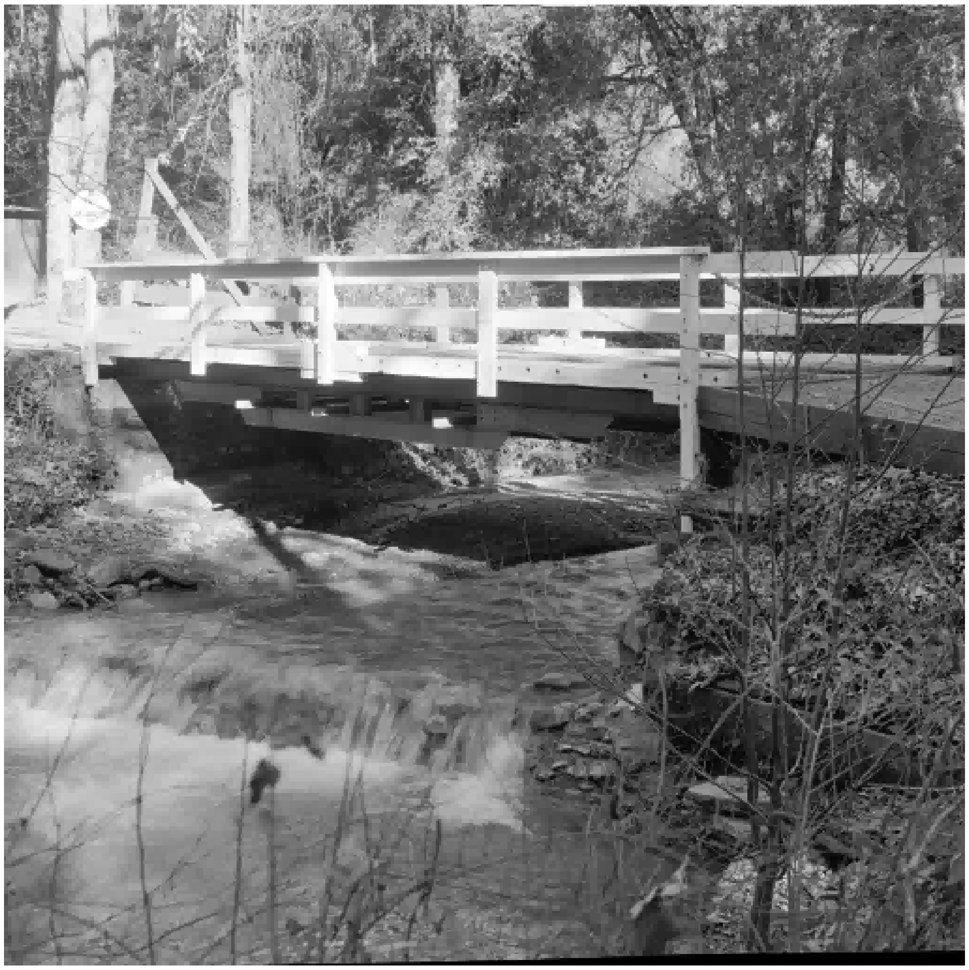


Figure 1: Original image

I got identical smoothed images for all the three versions. This is shown later by applying diff across these images.

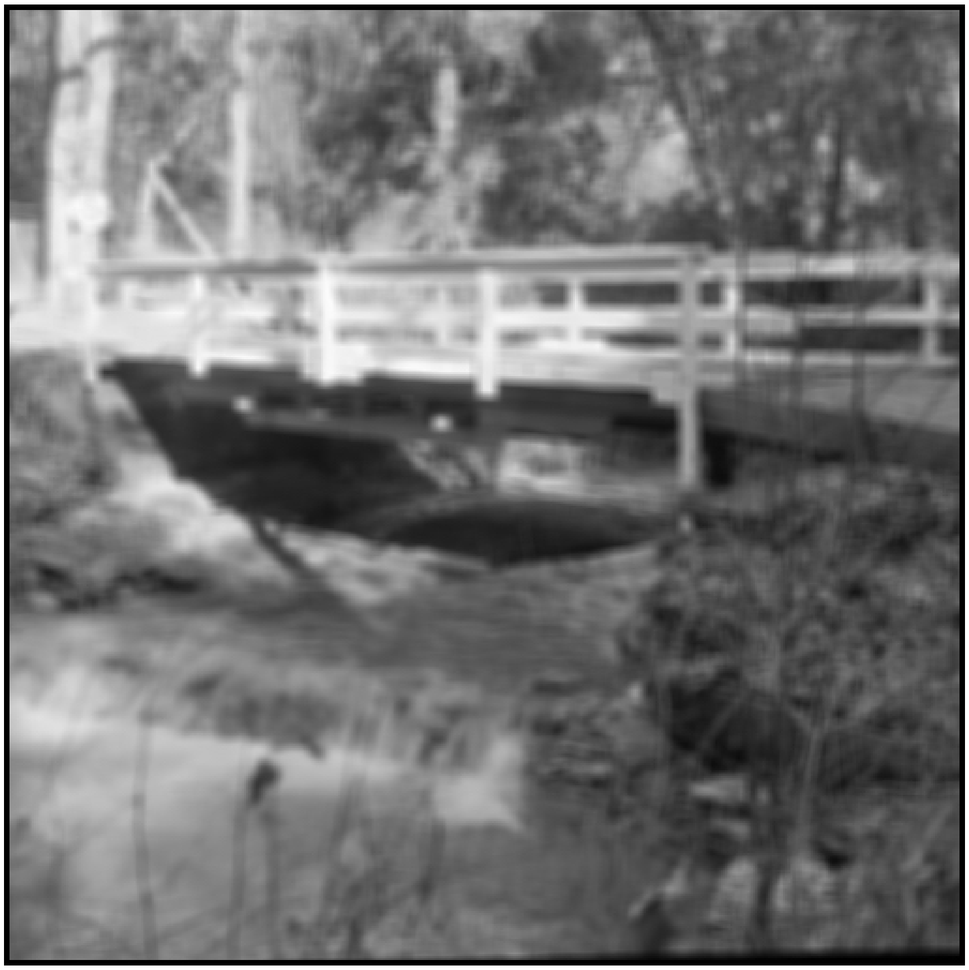


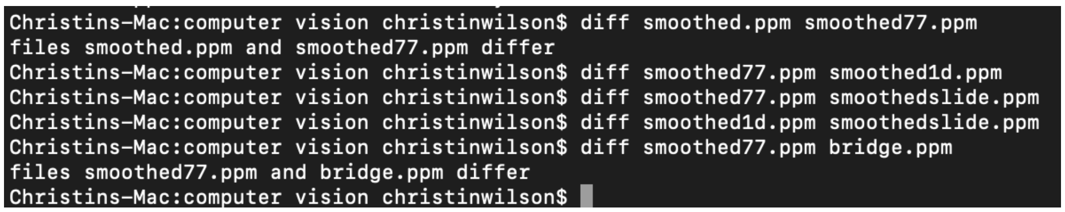
Figure 2: Smoothed image

3 Time Comparisons: (in picoseconds)

From the average time it took for each version, we can see that the separable filters takes much less time (12.7512 picoseconds) when compared to the 2d convolution filter (33.2771 picoseconds). This can further be reduced by using the sliding window approach which took an average of 7.2248 picoseconds.

No	2D Convolution	Seperable filters	Separable filters + Sliding window
1	32.246	11.276	6.754
2	31.295	13.441	7.361
3	31.295	11.949	8.316
4	32.204	14.020	6.874
5	32.938	12.795	7.401
6	32.123	12.826	6.873
7	36.581	13.341	6.727
8	34.216	11.160	7.105
9	34.261	13.581	7.329
10	34.747	13.123	7.508
AVG:	33.2771	12.7512	7.2248

4 Diff Checker



```
Christins-Mac:computer vision christinwilson$ diff smoothed.ppm smoothed77.ppm
files smoothed.ppm and smoothed77.ppm differ
Christins-Mac:computer vision christinwilson$ diff smoothed77.ppm smoothed1d.ppm
Christins-Mac:computer vision christinwilson$ diff smoothed77.ppm smoothedslide.ppm
Christins-Mac:computer vision christinwilson$ diff smoothed1d.ppm smoothedslide.ppm
Christins-Mac:computer vision christinwilson$ diff smoothed77.ppm bridge.ppm
files smoothed77.ppm and bridge.ppm differ
Christins-Mac:computer vision christinwilson$
```

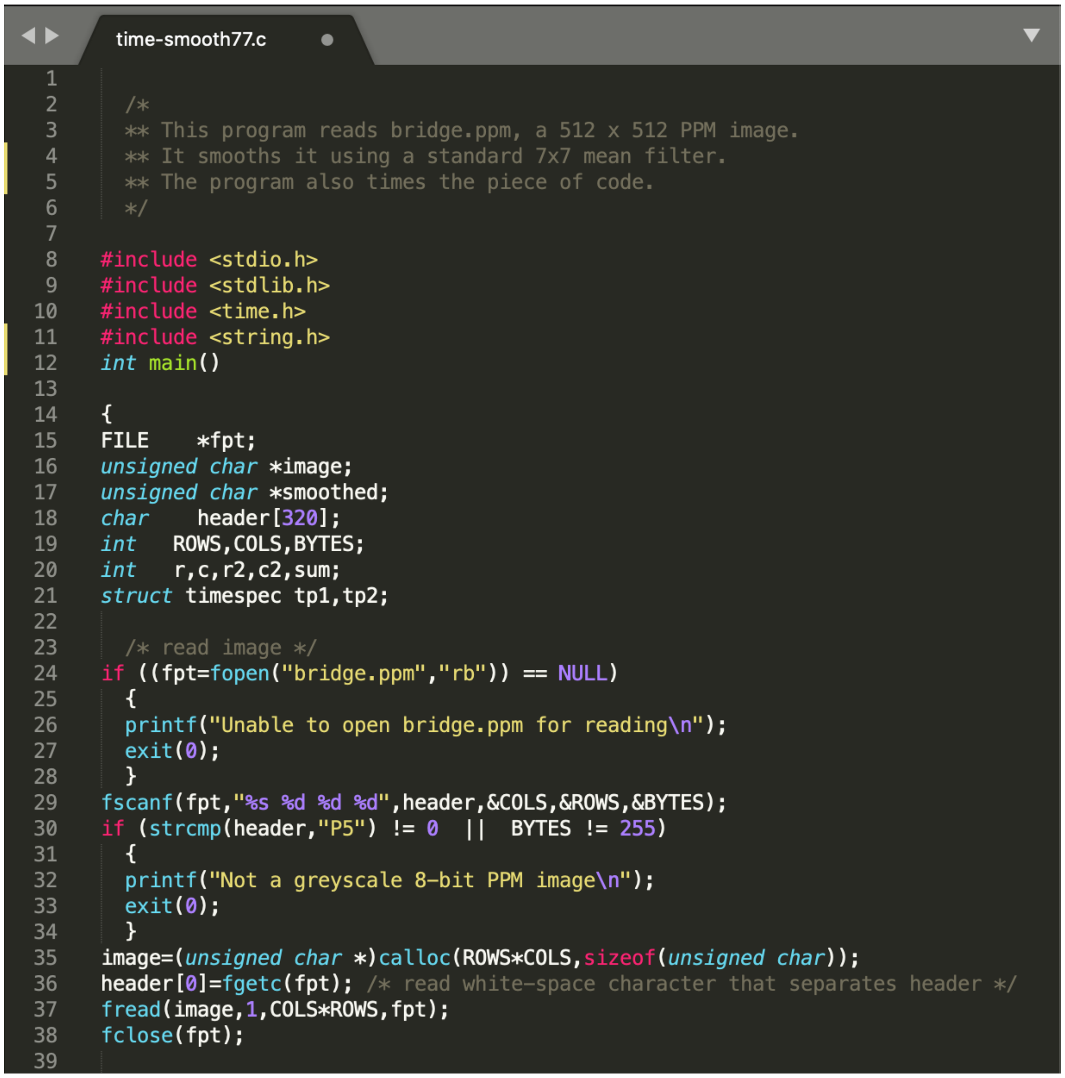
Figure 3: Screenshot of the terminal

As already stated above, comparing the 3 versions of the images from each other using 'diff' proves that the generated images are identical with each other but different from the original and the output image generated by 3x3 filter.

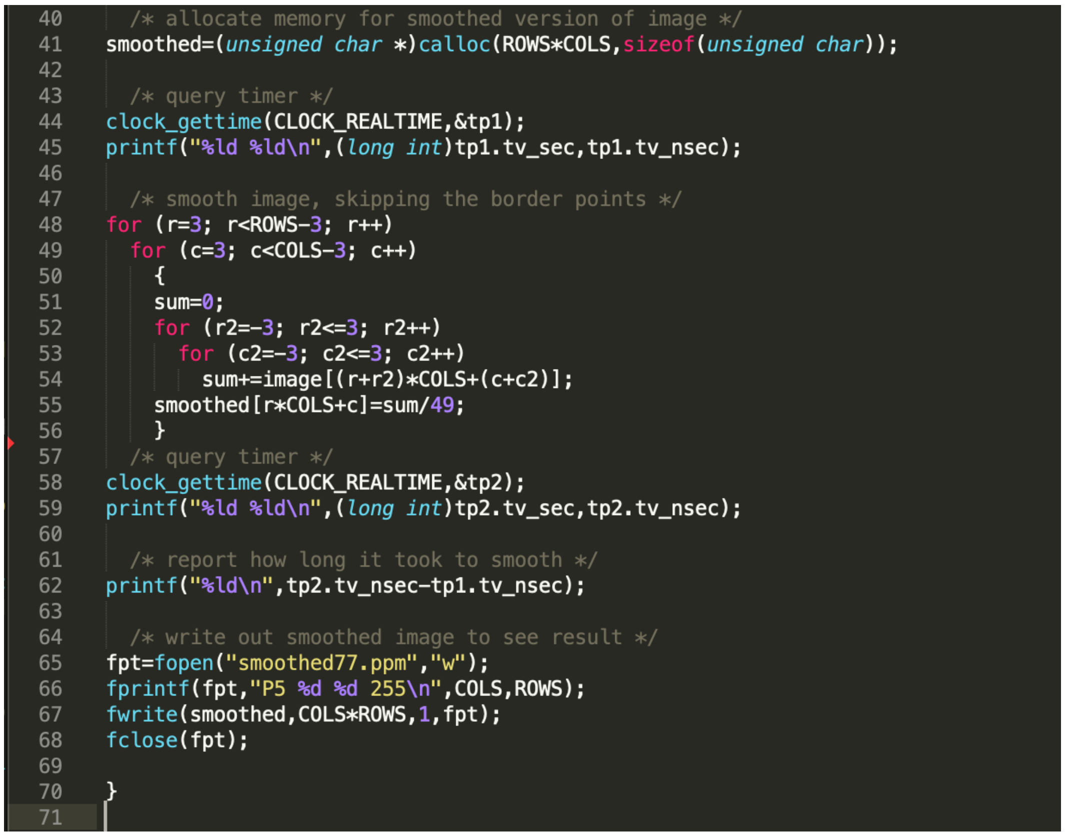
bridge.ppm	Input image
smoothed.ppm	2D convolution generated (3x3)
smoothed77.ppm	2D convolution generated (7x7)
smoothed1d.ppm	Separable filters generated
smoothedslide.ppm	Separable filters and sliding window generated

5 Source code

5.1 2D convolution

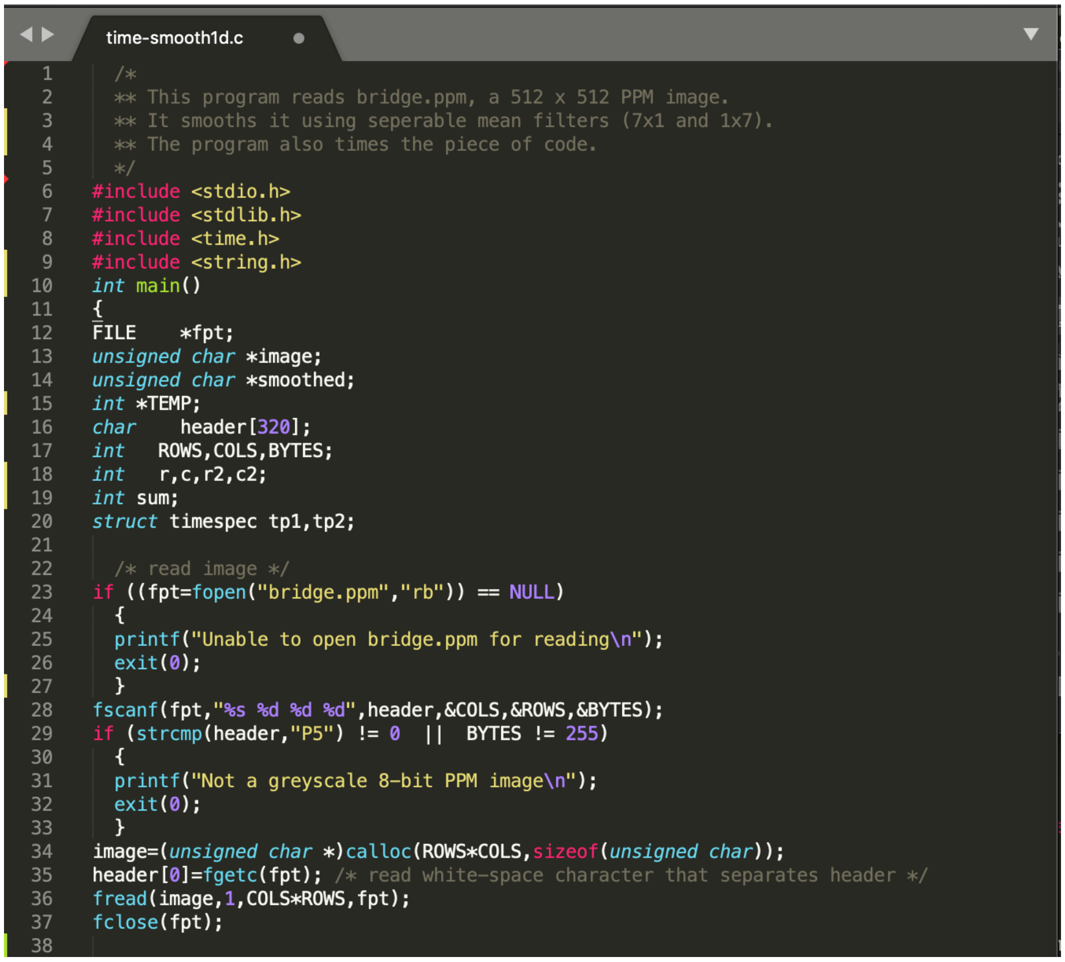


```c

  /*
  ** This program reads bridge.ppm, a 512 x 512 PPM image.
  ** It smooths it using a standard 7x7 mean filter.
  ** The program also times the piece of code.
  */

#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <string.h>
int main()

{
FILE    *fpt;
unsigned char *image;
unsigned char *smoothed;
char     header[320];
int    ROWS,COLS,BYTES;
int    r,c,r2,c2,sum;
struct timespec tp1,tp2;

  /* read image */
if ((fpt=fopen("bridge.ppm","rb")) == NULL)
  {
  printf("Unable to open bridge.ppm for reading\n");
  exit(0);
  }
fscanf(fpt,"%s %d %d %d",header,&COLS,&ROWS,&BYTES);
if (strcmp(header,"P5") != 0  ||  BYTES != 255)
  {
  printf("Not a greyscale 8-bit PPM image\n");
  exit(0);
  }
image=(unsigned char *)calloc(ROWS*COLS,sizeof(unsigned char));
header[0]=fgetc(fpt); /* read white-space character that separates header */
fread(image,1,COLS*ROWS,fpt);
fclose(fpt);

```

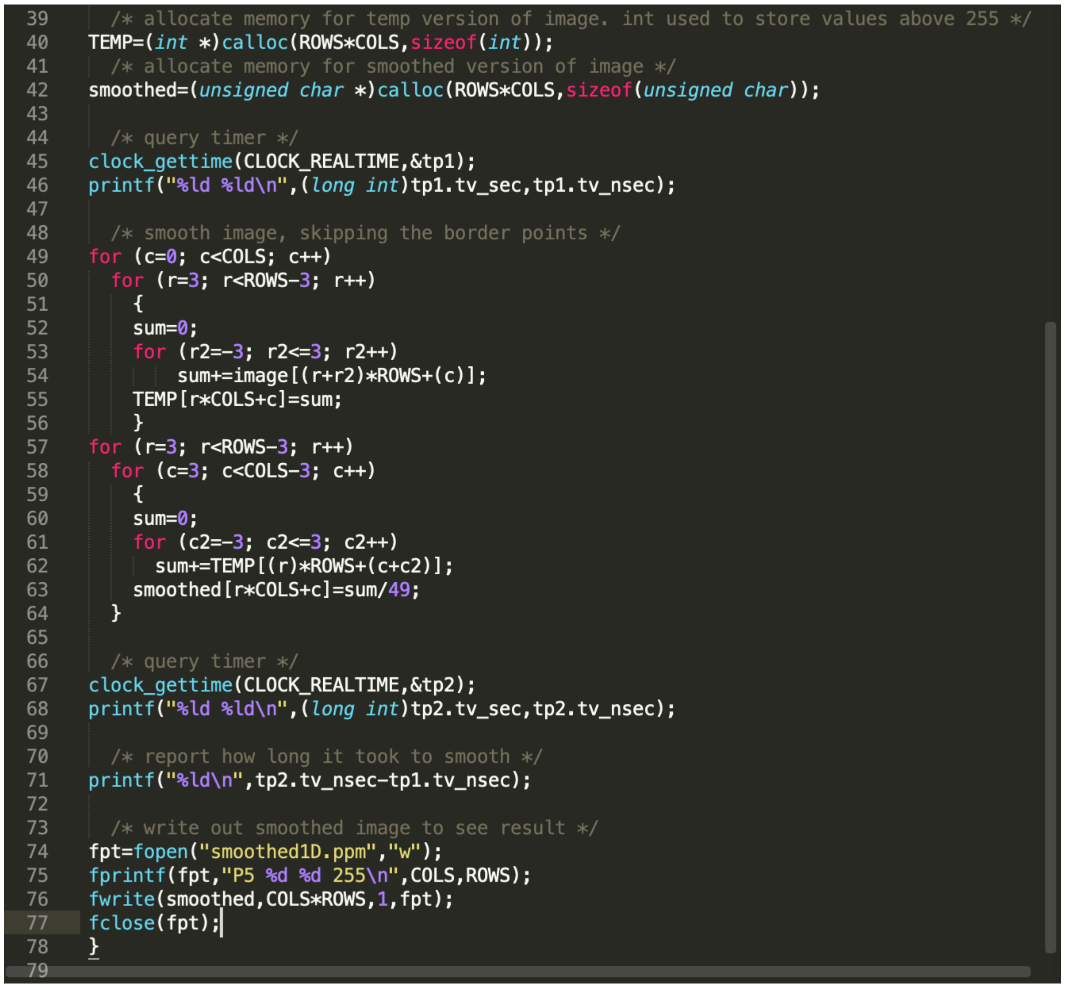


```
  /* allocate memory for smoothed version of image */
smoothed=(unsigned char *)calloc(ROWS*COLS,sizeof(unsigned char));

  /* query timer */
clock_gettime(CLOCK_REALTIME,&tp1);
printf("%ld %ld\n",(long int)tp1.tv_sec,tp1.tv_nsec);

  /* smooth image, skipping the border points */
for (r=3; r<ROWS-3; r++)
  for (c=3; c<COLS-3; c++)
    {
    sum=0;
    for (r2=-3; r2<=3; r2++)
      for (c2=-3; c2<=3; c2++)
        sum+=image[(r+r2)*COLS+(c+c2)];
    smoothed[r*COLS+c]=sum/49;
    }
  /* query timer */
clock_gettime(CLOCK_REALTIME,&tp2);
printf("%ld %ld\n",(long int)tp2.tv_sec,tp2.tv_nsec);

  /* report how long it took to smooth */
printf("%ld\n",tp2.tv_nsec-tp1.tv_nsec);

  /* write out smoothed image to see result */
fpt=fopen("smoothed77.ppm","w");
fprintf(fpt,"P5 %d %d 255\n",COLS,ROWS);
fwrite(smoothed,COLS*ROWS,1,fpt);
fclose(fpt);

}
```

5.2 Separable filters

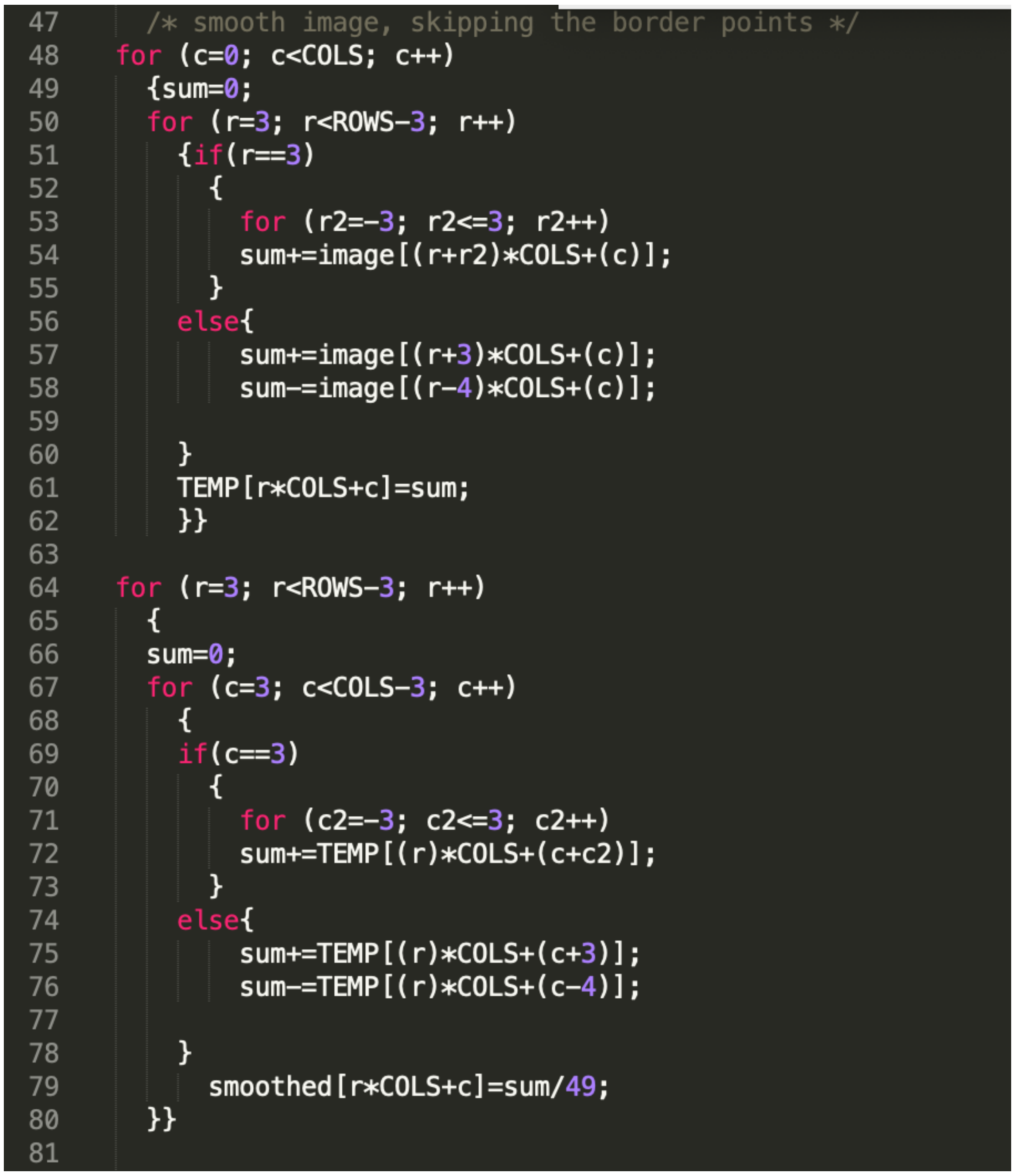


```c
  /*
  ** This program reads bridge.ppm, a 512 x 512 PPM image.
  ** It smooths it using seperable mean filters (7x1 and 1x7).
  ** The program also times the piece of code.
  */
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <string.h>
int main()
{
FILE    *fpt;
unsigned char *image;
unsigned char *smoothed;
int *TEMP;
char     header[320];
int   ROWS,COLS,BYTES;
int   r,c,r2,c2;
int sum;
struct timespec tp1,tp2;

  /* read image */
if ((fpt=fopen("bridge.ppm","rb")) == NULL)
  {
  printf("Unable to open bridge.ppm for reading\n");
  exit(0);
  }
fscanf(fpt,"%s %d %d %d",header,&COLS,&ROWS,&BYTES);
if (strcmp(header,"P5") != 0  ||  BYTES != 255)
  {
  printf("Not a greyscale 8-bit PPM image\n");
  exit(0);
  }
image=(unsigned char *)calloc(ROWS*COLS,sizeof(unsigned char));
header[0]=fgetc(fpt); /* read white-space character that separates header */
fread(image,1,COLS*ROWS,fpt);
fclose(fpt);

```



```
 /* allocate memory for temp version of image. int used to store values above 255 */
TEMP=(int *)calloc(ROWS*COLS,sizeof(int));
 /* allocate memory for smoothed version of image */
smoothed=(unsigned char *)calloc(ROWS*COLS,sizeof(unsigned char));

 /* query timer */
clock_gettime(CLOCK_REALTIME,&tp1);
printf("%ld %ld\n",(long int)tp1.tv_sec,tp1.tv_nsec);

 /* smooth image, skipping the border points */
for (c=0; c<COLS; c++)
 for (r=3; r<ROWS-3; r++)
  {
  sum=0;
  for (r2=-3; r2<=3; r2++)
    sum+=image[(r+r2)*ROWS+(c)];
  TEMP[r*COLS+c]=sum;
  }
for (r=3; r<ROWS-3; r++)
 for (c=3; c<COLS-3; c++)
  {
  sum=0;
  for (c2=-3; c2<=3; c2++)
   sum+=TEMP[(r)*ROWS+(c+c2)];
  smoothed[r*COLS+c]=sum/49;
 }

 /* query timer */
clock_gettime(CLOCK_REALTIME,&tp2);
printf("%ld %ld\n",(long int)tp2.tv_sec,tp2.tv_nsec);

 /* report how long it took to smooth */
printf("%ld\n",tp2.tv_nsec-tp1.tv_nsec);

 /* write out smoothed image to see result */
fpt=fopen("smoothed1D.ppm","w");
fprintf(fpt,"P5 %d %d 255\n",COLS,ROWS);
fwrite(smoothed,COLS*ROWS,1,fpt);
fclose(fpt);
}
```

5.3 Separable filters + Sliding window



```
    /* smooth image, skipping the border points */
  for (c=0; c<COLS; c++)
    {sum=0;
    for (r=3; r<ROWS-3; r++)
      {if(r==3)
        {
          for (r2=-3; r2<=3; r2++)
          sum+=image[(r+r2)*COLS+(c)];
        }
      else{
          sum+=image[(r+3)*COLS+(c)];
          sum-=image[(r-4)*COLS+(c)];

      }
      TEMP[r*COLS+c]=sum;
      }}

  for (r=3; r<ROWS-3; r++)
    {
    sum=0;
    for (c=3; c<COLS-3; c++)
      {
      if(c==3)
        {
          for (c2=-3; c2<=3; c2++)
          sum+=TEMP[(r)*COLS+(c+c2)];
        }
      else{
          sum+=TEMP[(r)*COLS+(c+3)];
          sum-=TEMP[(r)*COLS+(c-4)];

      }
        smoothed[r*COLS+c]=sum/49;
    }}

```