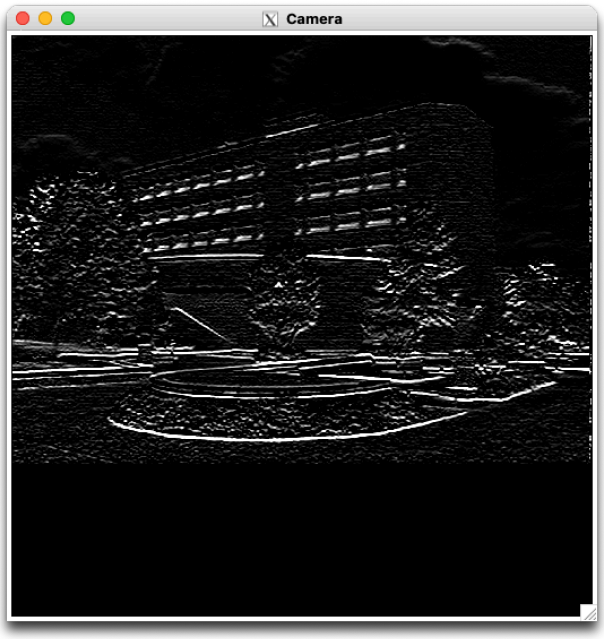
Hyun Ho Kim 1001967176

1. Implement Edge Detection Using Sobel Templates
   - Sobel Vertical
     - Description:

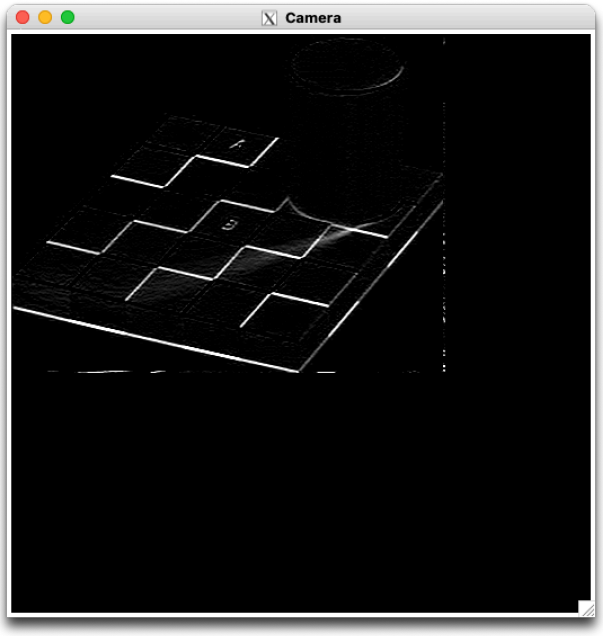
Vertical template: $\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$

By comparing a 3x3 pixel area in the image with each template, the system assesses the similarity of this region to the provided template. In the context of vertical edge detection, a high value indicates that the template has identified a vertical edge in the image.

Nedderman Hall



Chess board



- Sobel Horizontal
  - Description:

Horizontal template: $\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$

By comparing a 3x3 pixel area in the image with each template, the system assesses the similarity of this region to the provided template. In the context of horizontal edge detection, a high value indicates that the template has identified a horizontal edge in the image.

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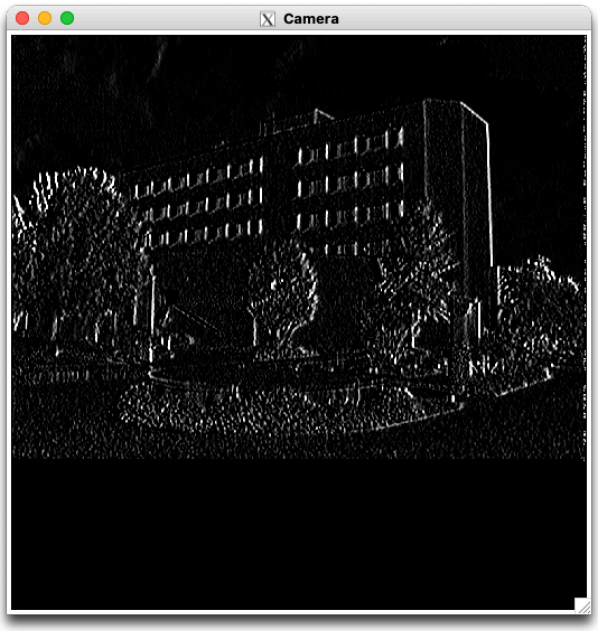
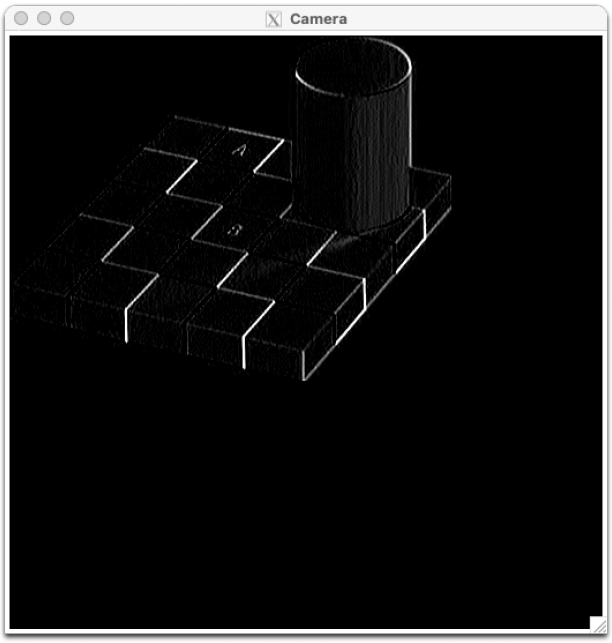


Chess board



- Sobel Major Diagonal
  - Description:

Major Diagonal template: $\begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}$

By comparing a 3x3 pixel area in the image with each template, the system assesses the similarity of this region to the provided template. In the context of major diagonal edge detection, a high value indicates that the template has identified a major diagonal edge in the image.

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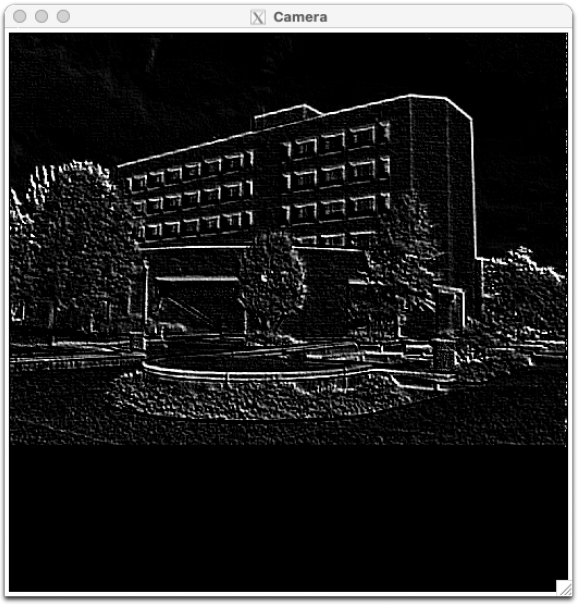
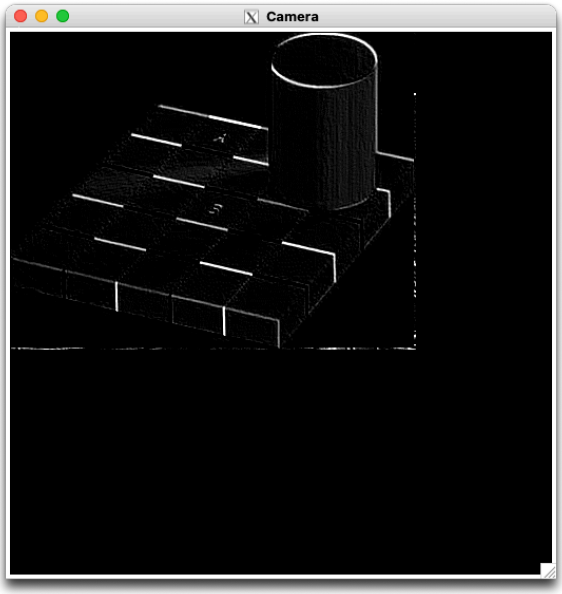


Chess board



- Sobel Minor Diagonal
  - Description:

Minor Diagonal template: $\begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$

By comparing a 3x3 pixel area in the image with each template, the system assesses the similarity of this region to the provided template. In the context of minor diagonal edge detection, a high value indicates that the template has identified a minor diagonal edge in the image.

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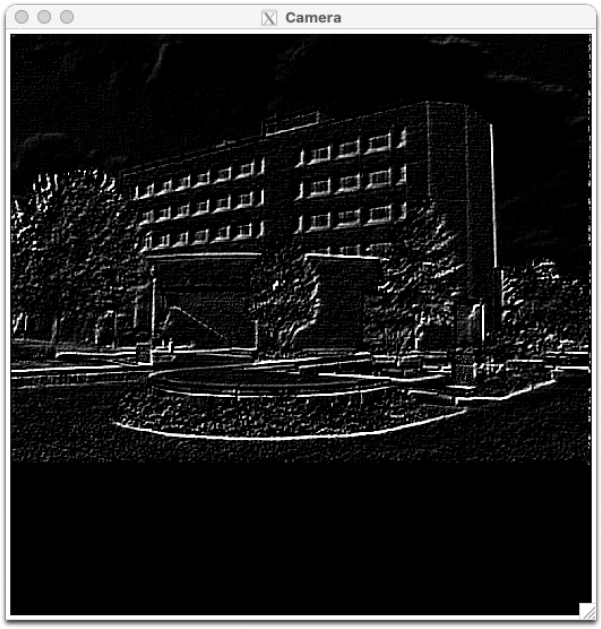
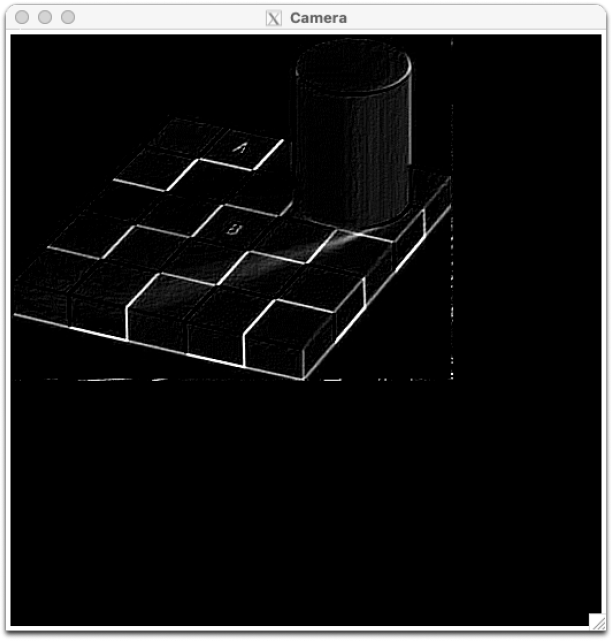


Chess board



Code:

```
#include <stdio.h>
#include <math.h>
#include <X11/Xlib.h>

#define DIM 512

/*****************************************************************/
/* This structure contains the coordinates of a box drawn with   */
/* the left mouse button on the image window.                    */
/* roi.x , roi.y  - left upper corner's coordinates              */
/* roi.width , roi.height - width and height of the box          */
/*****************************************************************/
extern XRectangle roi;

unsigned char convolution(unsigned char image[DIM][DIM],int template[3][3],int row,int col);
/*****************************************************************/
/* Main processing routine. This is called upon pressing the     */
/* Process button of the interface.                              */
/* image  - the original greyscale image                         */
/* size   - the actual size of the image                         */
/* proc_image - the image representation resulting from the      */
/*            processing. This will be displayed upon return     */
/*            from this function.                                */
/*****************************************************************/
void process_image(image, size, proc_img)
unsigned char image[DIM][DIM];
int size[2];
unsigned char proc_img[DIM][DIM];
{
   // Sobel templates
   // Please uncomment the desired template as a parameter in the convolution function
   // int sobelVertical[3][3] = {{-1, 0, 1}, {-2, 0, 2}, {-1, 0, 1}};
   // int sobelHorizontal[3][3] = {{-1, -2, -1}, {0, 0, 0}, {1, 2, 1}};
   // int sobelMajDiag[3][3] = {{0, -1, -2}, {1, 0, -1}, {2, 1, 0}};
   int sobelMinDiag[3][3] = {{-2, -1, 0}, {-1, 0, 1}, {0, 1, 2}};

   for (int x = 0; x < size[0] - 2; x++)
   {
      for (int y = 0; y < size[1] - 2; y++)
      {
         proc_img[x][y] = convolution(image,sobelMinDiag,x,y); // switch the second parameter, if
needed.
      }
```

```
    }
}
unsigned char convolution(unsigned char image[DIM][DIM],int template[3][3],int row,int col)
{
    int sum = 0;
    for (int i = 0; i < 3; i++)
    {
        for (int j = 0; j < 3; j++)
        {
            sum += (int)image[row + i][col + j] * template[i][j];
        }
    }
    // check if sum is out of range [0:255]
    if (sum < 0)
    {
        sum = 0;
    }
    else if (sum > 255)
    {
        sum = 255;
    }
    return (unsigned char)sum;
}
```

2. Implement Template Matching Using Normalized Convolution

- Description:

Formula used: $$\frac{1}{n}\sum_{x,y}\frac{1}{\sigma_f\sigma_t}\left(f(x,y)-\mu_f\right)\left(t(x,y)-\mu_t\right)$$

Normalized Convolution calculates the cross-correlation between a portion of an image and a selected template, providing a measure of similarity. Both the image and the template need to undergo normalization before the cross-correlation process. The brighter the area, the more similar it is to the template.

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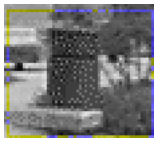
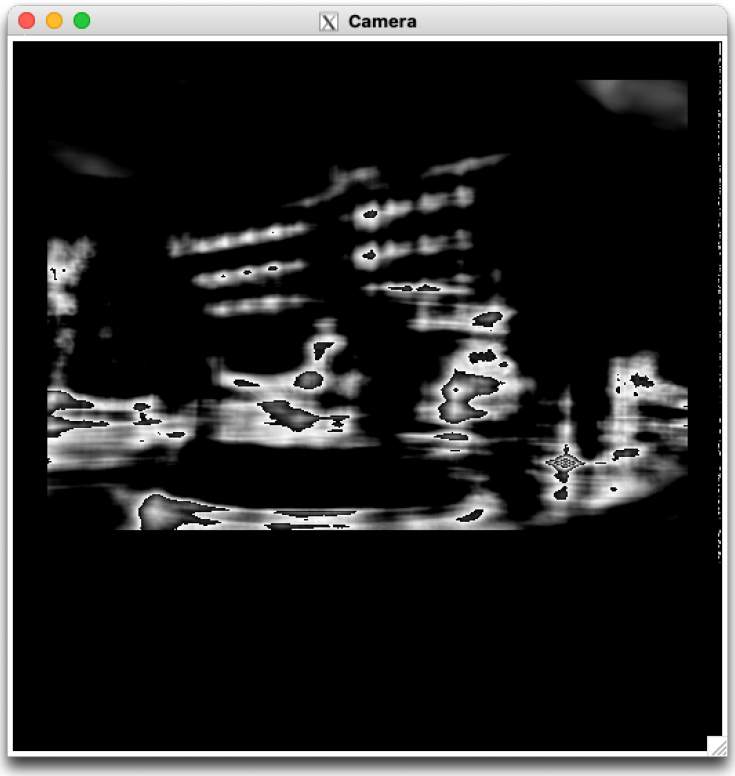
Template: 

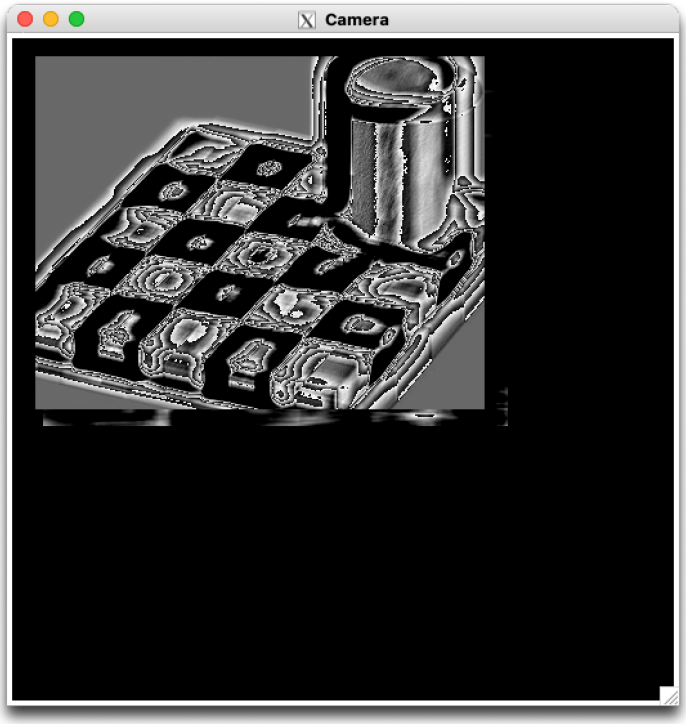
Result:



- Chess board

Template: 

Result:



Code:

```
#include <stdio.h>
#include <math.h>
#include <X11/Xlib.h>

#define DIM 512

extern XRectangle roi;

float convolution(unsigned char image[DIM][DIM], float template[roi.width][roi.height], int row,
int col, float template_mean, float template_stddev);
void normalize(float data[roi.width][roi.height], float mean, float stddev);
void get_mean_stddev(float data[roi.width][roi.height], float *mean, float *stddev);

void process_image(unsigned char image[DIM][DIM], int size[2], unsigned char
proc_img[DIM][DIM])
{
   // selected templates
   float template[roi.width][roi.height];
   float template_mean, template_stddev;

   // extracting template from image
   for (int x = 0; x < roi.width; x++)
   {
      for (int y = 0; y < roi.height; y++)
      {
         template[x][y] = (float)image[roi.x + x][roi.y + y];
      }
   }

   get_mean_stddev(template, &template_mean, &template_stddev);
   normalize(template, template_mean, template_stddev);

   for (int x = 0; x < size[0]-roi.width; x++)
   {
      for (int y = 0; y < size[1]-roi.height; y++)
      {
         float conv_result = convolution(image, template, x, y, template_mean, template_stddev);
         // Normalize the result of the convolution to be between 0 and 255
         proc_img[x + roi.width / 2][y + roi.height / 2] = (unsigned char)(conv_result * 255.0f);
      }
   }
}
```

```
float convolution(unsigned char image[DIM][DIM], float template[roi.width][roi.height], int row,
int col, float template_mean, float template_stddev)
{
   float sum = 0.0;
   float n = roi.height * roi.width;
   float subimage_mean, subimage_stddev;
   float subimage[roi.width][roi.height];

   // Extract subimage and calculate its mean and standard deviation
   for (int x = 0; x < roi.width-1; x++)
   {
      for (int y = 0; y < roi.height-1; y++)
      {
         subimage[x][y] = (float)image[row+x][col+y];
      }
   }
   get_mean_stddev(subimage, &subimage_mean, &subimage_stddev);
   normalize(subimage, subimage_mean, subimage_stddev);

   // Perform normalized cross-correlation
   for (int i = 0; i < roi.width; i++)
   {
      for (int j = 0; j < roi.height; j++)
      {
         sum += subimage[i][j] * (template[i][j] - template_mean) / template_stddev;
      }
   }

   sum = fmax(0.0, fmin(sum / n, 1.0)) * 255.0;

   return sum;
}

void normalize(float data[roi.width][roi.height], float mean, float stddev)
{
   // Normalize each pixel value using the mean and standard deviation
   for (int i = 0; i < roi.width; i++)
   {
      for (int j = 0; j < roi.height; j++)
      {
         data[i][j] = (data[i][j] - mean) / stddev;
      }
   }
}
```

```
void get_mean_stddev(float data[roi.width][roi.height], float *mean, float *stddev)
{
   *mean = 0.0;
   *stddev = 0.0;

   // Compute mean
   for (int i = 0; i < roi.width; i++)
   {
      for (int j = 0; j < roi.height; j++)
      {
         *mean += data[i][j];
      }
   }

   *mean /= (roi.width * roi.height);

   // Compute standard deviation
   for (int i = 0; i < roi.width; i++)
   {
      for (int j = 0; j < roi.height; j++)
      {
         *stddev += pow(data[i][j] - *mean, 2);
      }
   }

   *stddev /= (roi.width * roi.height);
   *stddev = sqrt(*stddev);
}
```