Parallel Image/Video Editor

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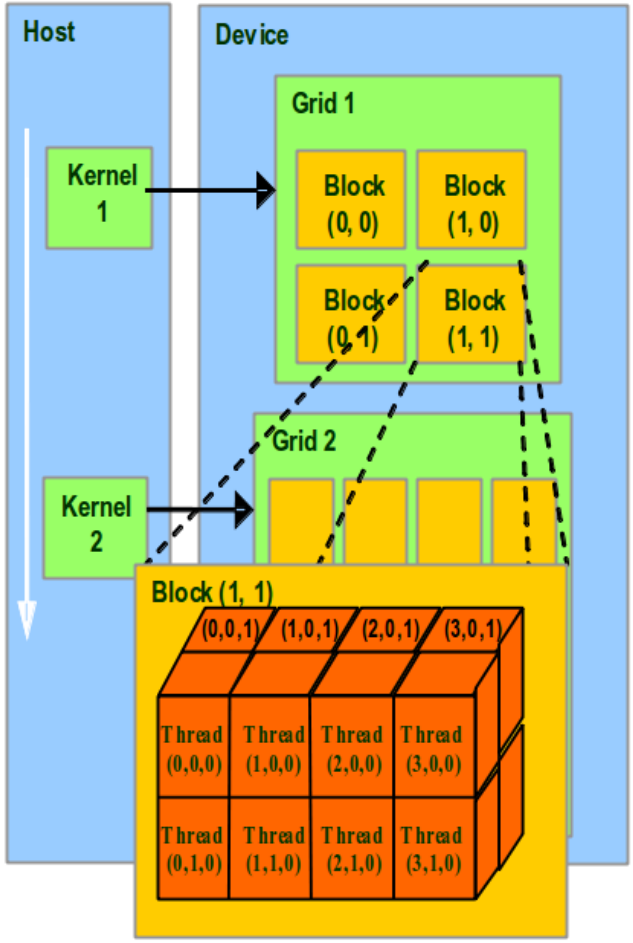
Project Overview

GPU-Parallelized Image and Video Editor

Multiple Encoding Algorithms

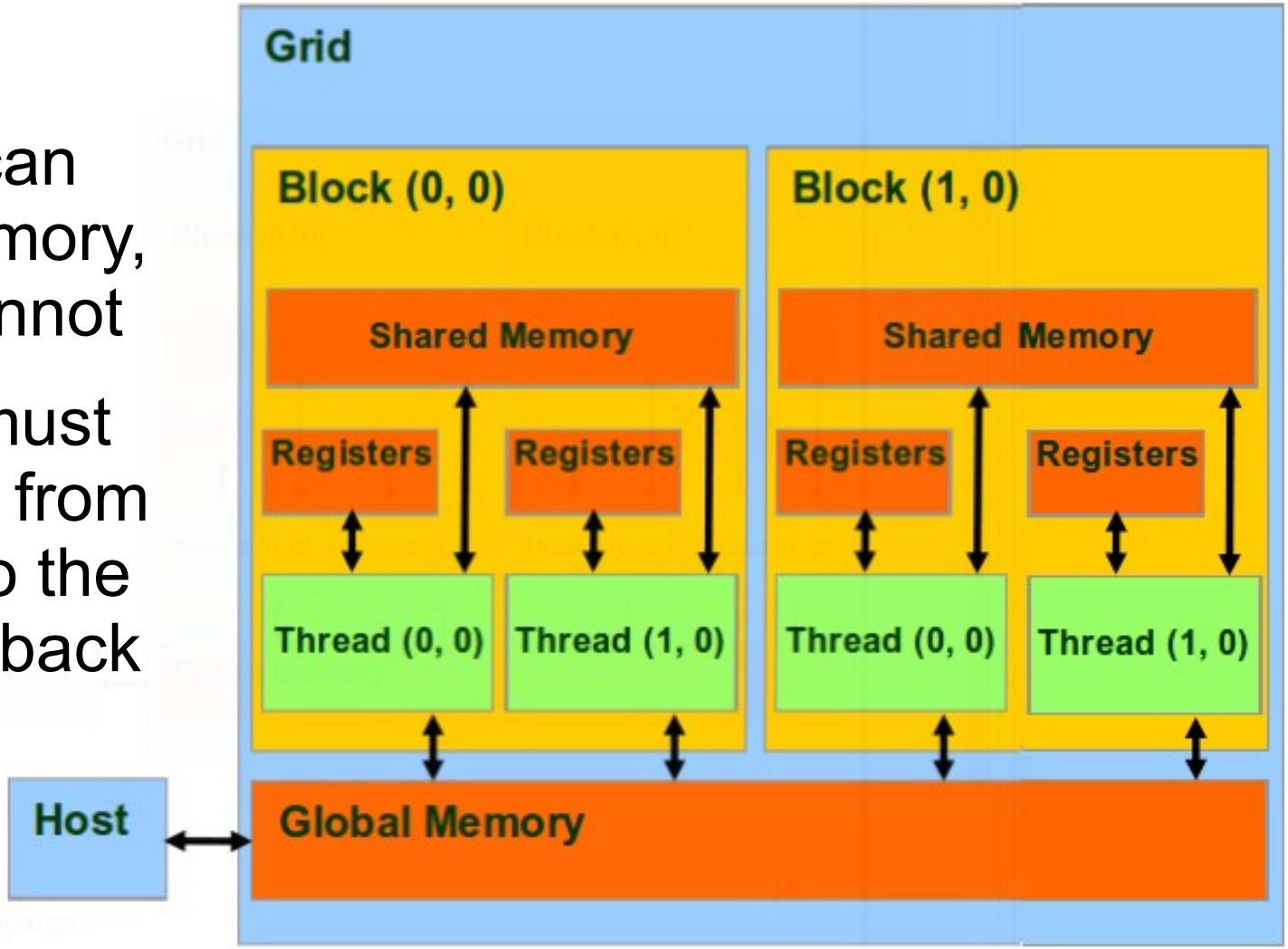
Nvidia's CUDA

- Compute-Unified Device Architecture
- GPU (grid) divided into Blocks, Threads
- Each Thread invokes the same kernel, preforms its own calculations



Nvidia's CUDA

- Threads can share memory, Blocks cannot
- Memory must be copied from the host to the GPU and back again



Qt

Cross-Platform C++ GUI Framework

Multi-threading, Multimedia, WebKit, SQL

GUI Demonstration

Image Editing

Grayscale

Brightness

Contrast

Saturation

Crop

Rotate

Scale

Blur

Edge Detect

Grayscale

```
// Replace each RGB with the luminance value


for(int y = 0; y < img->height(); y++) {
     for(int x = 0; x < img->width(); x++) {
          QRgb p = img->pixel(x, y);
          r = g = b = (qRed(p) * 0.3) + (qGreen(p) * 0.59) + (qBlue(p) * 0.11);
          img->setPixel(x, y, qRgb(r, g, b));
     }
}
return img;
```

GPU: Grayscale

```
extern "C" void CUgreyscale(unsigned char* output, unsigned char* input, int row, int col);

void CUgreyscale(unsigned char* output, unsigned char* input, int row, int col)
{
     dim3 dimGrid(row/16+1, col/16+1);
     dim3 dimThreadBlock(16,16);
     greyscale<<<dimGrid, dimThreadBlock>>>(input, output, row, col);
}

__global__ void greyscale(unsigned char* input, unsigned char* output, int row, int col)
{
     int xIndex = blockDim.x * blockIdx.x + threadIdx.x;
     int yIndex = blockDim.y * blockIdx.y + threadIdx.y;
     int index = (4*xIndex + yIndex * row*4);

     if(index < row*col*4){
          int lum = 0.11*input[index] + 0.59*input[index+1] + 0.3*input[index+2];

          output[index]=lum;
          output[index+1]=lum;
          output[index+2]=lum;
          output[index+3]=0;
     }
}
```

Brightness

```
// Scale each RGB value by the brightening factor


for(int y = 0; y < img->height(); y++) {
     for(int x = 0; x < img->width(); x++) {
          QRgb p = img->pixel(x, y);
          int r = qRed(p) * factor;
          int g = qGreen(p) * factor;
          int b = qBlue(p) * factor;
          // Clamp color values
          img->setPixel(x, y, qRgb(r, g, b));
     }
}
return img;
```

Contrast

```
// Scale each RGB value away from the average luminosity


for(int y = 0; y < img->height(); y++) {
     for(int x = 0; x < img->width(); x++) {
          QRgb p = img->pixel(x, y);
          int r = (1-factor)*average_lum + factor*(qRed(p));
          int g = (1-factor)*average_lum + factor*(qGreen(p));
          int b = (1-factor)*average_lum + factor*(qBlue(p));
          // Clamp color values
          img->setPixel(x, y, qRgb(r, g, b));
     }
}
return img;
```

Saturation

```
// Scale each RGB value away from its luminosity


for(int y = 0; y < img->height(); y++) {
     for(int x = 0; x < img->width(); x++) {
          QRgb p = img->pixel(x, y);
          float lum = (qRed(p) * 0.3) + (qGreen(p) * 0.59) + (qBlue(p) * 0.11);
          int r = (1-factor)*lum + factor*(qRed(p));
          int g = (1-factor)*lum + factor*(qGreen(p));
          int b = (1-factor)*lum + factor*(qBlue(p));
          // Clamp color values
          img->setPixel(x, y, qRgb(r, g, b));
     }
}
return img;
```

Crop

```
// Validate input dimensions and coordinates


// Copy pixels within the coordinates
for(int x = leftX; x < rightX; x++) {
     for(int y = leftY; y < rightY; y++)
          img->setPixel(x-leftX, y-leftY, img->pixel(x,y));
}
return img;
```

Rotate

```
// Determine new dimensions


// Rotate the image
for(int x = 0; x < newWidth; x++) {
     for(int y = 0; y < newHeight; y++) {
          float u = cos(-1*a)*(x-newxcenter) - sin(-1*a)*(y-newycenter)+width/2;
          float v = sin(-1*a)*(x-newxcenter) + cos(-1*a)*(y-newycenter)+height/2;
          // Perform Gaussian sampling to determine pixel color
          newImg->setPixel(x, y, Utility::GaussianSample(img, u, v, 0.6, 4));
     }
}
return newImg;
```

Scale

```
// Determine new dimensions


// Scale the image
for(int x = 0; x < newWidth; x++) {
     for(int y = 0; y < newHeight; y++) {
          float u = 1/factor*x;
          float v = 1/factor*y;
          // Perform sampling to determine pixel color
          newImg->setPixel(x, y, Utility::GaussianSample(img, u, v, 0.6,
2*factor));
     }
}
return newImg;
```

Blur

```
// Convolution mask
float mask[3][3] = { {1/16.0, 2/16.0, 1/16.0}, {2/16.0, 4/16.0,
2/16.0}, {1/16.0, 2/16.0, 1/16.0} };

for(int y = 0; y < height; y++) {
     for(int x = 0; x < width; x++) {
          int r = 0, g = 0, b = 0;
          for(int i = 0; i <= 2; i++) {
             for(int j = 0; j <= 2; j++) {
                    QRgb pixel = img->pixel(x+(j-1), y+(i-1));
                    r += mask[i][j]*qRed(pixel);
                    g += mask[i][j]*qGreen(pixel);
                    b += mask[i][j]*qBlue(pixel);
               }
          }
          // Clamp color values
     }
}
newImg->setPixel(x, y, qRgb(r, g, b));
return newImg;
```

Edge Detect

```
// Convolution mask
float mask[3][3] = { {-1.0, -1.0, -1.0}, {-1.0, 8.0, -1.0}, {-1.0,
-1.0, -1.0} };

for(int y = 0; y < height; y++) {
     for(int x = 0; x < width; x++) {
          int r = 0, g = 0, b = 0;
          for(int i = 0; i <= 2; i++) {
             for(int j = 0; j <= 2; j++) {
                    QRgb pixel = img->pixel(x+(j-1), y+(i-1));
                    r += mask[i][j]*qRed(pixel);
                    g += mask[i][j]*qGreen(pixel);
                    b += mask[i][j]*qBlue(pixel);
               }
          }
          // Clamp color values
     }
}
newImg->setPixel(x, y, qRgb(r, g, b));
return newImg;
```

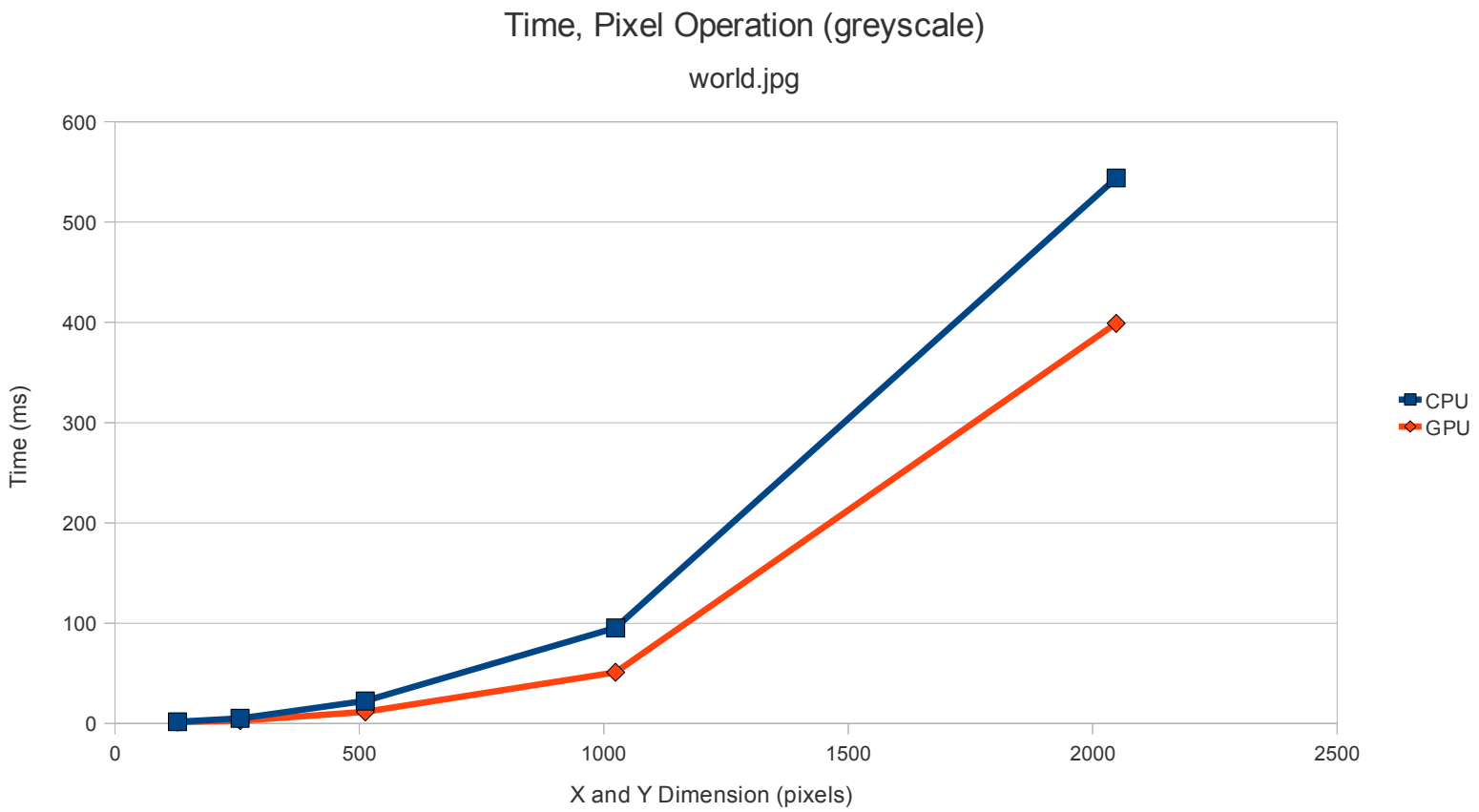
GPU: Edge Detect

```
extern "C" void CUedgeDetect(unsigned char* input, unsigned char* output, int row, int
col);

void CUedgeDetect(unsigned char* output, unsigned char* input, int row, int col)
{
    dim3 dimGrid(row/4+1, col/4+1);
    dim3 dimThreadBlock(16,16);

    float coeff[9]= {-1, -1, -1, \
                     -1,  8, -1, \
                     -1, -1, -1};
    float* CUcoeff;
    cutilSafeCall(cudaMalloc((void**)&CUcoeff, sizeof(float)*9));
    cutilSafeCall(cudaMemcpy(CUcoeff, coeff, sizeof(float)*9, cudaMemcpyHostToDevice));

    conv3x3<<<dimGrid, dimThreadBlock>>>(input, output, row, col, CUcoeff);
    cutilSafeCall(cudaFree(CUcoeff));
}
```

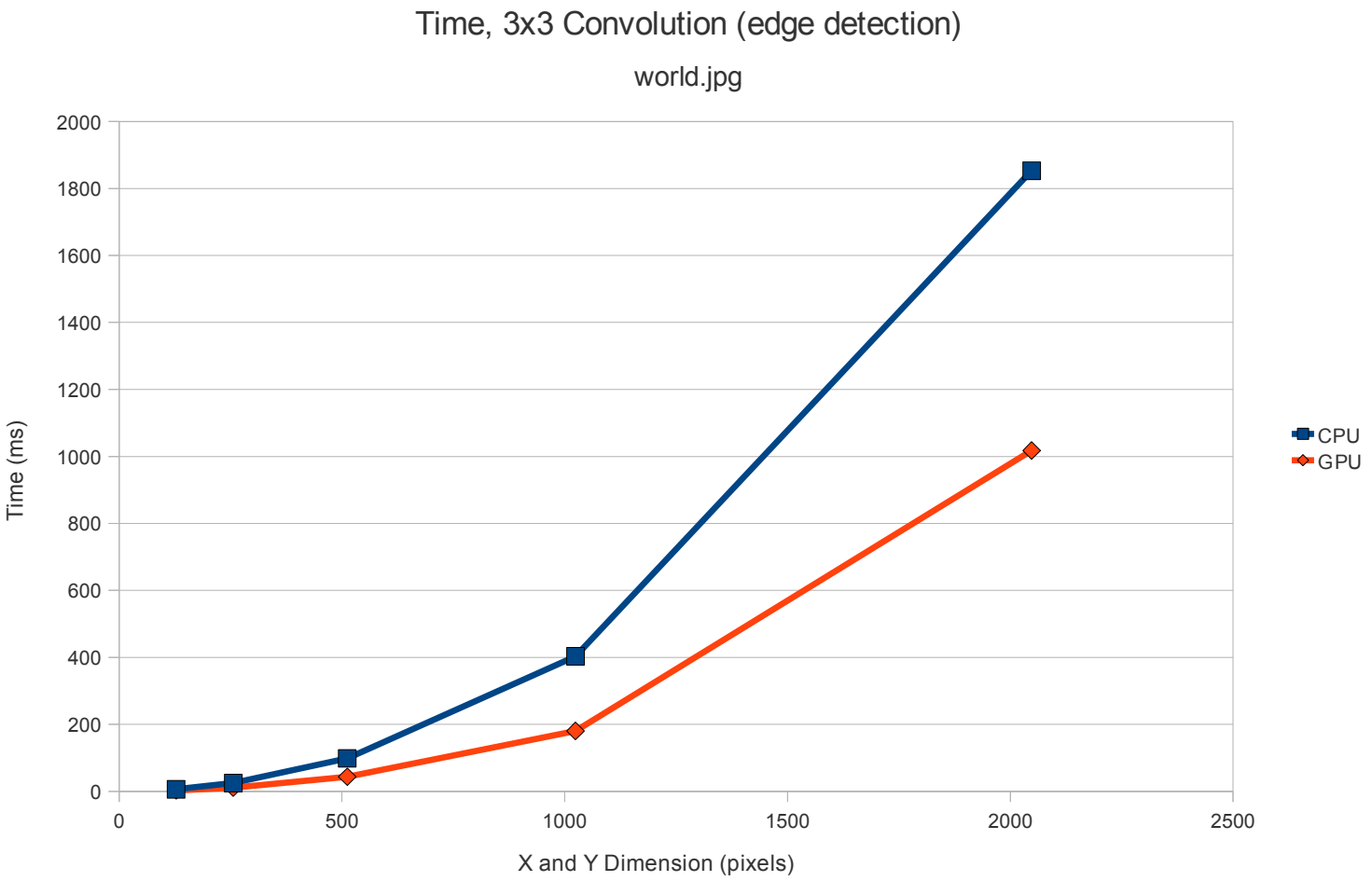
GPU: Edge Detect

```
__global__ void conv3x3(unsigned char* input, unsigned char* output, int row, int col,
float* kernel)
{
     int xIndex = blockDim.x * blockIdx.x + threadIdx.x;
     int yIndex = blockDim.y * blockIdx.y + threadIdx.y;
     int index = (xIndex + yIndex * row*4);

     if(index < row*col*4){
          int i, j;
          float convSum=0;
          for(i=-1; i < 2; i++){
               for(j=-1; j < 2; j++){
                    if(-1 < (index+4*j)+(4*col*i) && (index+4*j)+(4*col*i) < row*col*4){
                    convSum += kernel[3*(i+1) + (j+1)]*input[(index+4*j)+(4*col*i)];
                    }
               }
          }
          output[index] = CLAMP(convSum);
     }
}
```

CPU vs GPU Speed Comparison



CPU vs GPU Speed Comparison



Decoding

QImage-provided support for .bmp, .gif, .jpg, .png, .pgm, and .tif decoding

Decoding implemented for custom .ppc codec

Image stored in 32-bit RGBA format internally

Encoding

QImage-provided support for .bmp, .jpg, .png, .tif encoding with quality setting option

Encoding implemented for custom .ppc codec

- Huffman Compression
- Arithmetic Compression
- Run Length Compression

Encoding

Sully.bmp: 329 Kb

None: 436 Kb

Run Length: 318 Kb

Huffman: 277 Kb

Arithmetic: 874 Kb

Huffman over Run Length: 260 Kb

Arithmetic over Run Length: 636 Kb

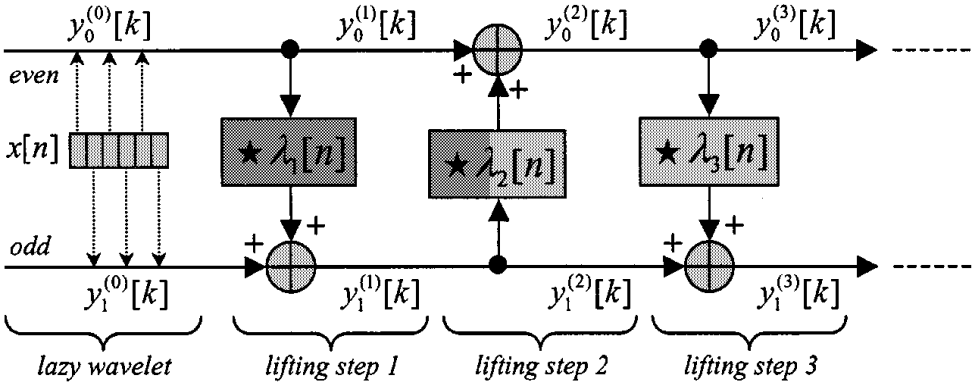
Arithmetic over Huffman: 554 Kb

Arithmetic over Huffman over Run Length: 528 Kb

.ppc Codec

```
void Encoder::write_ppc(QImage* img, QString filename, bool huffman, bool
arithmetic, bool runlength) {
     int mode = 4*runlength + 2*huffman + arithmetic;
     unsigned long numBytes = img->byteCount();
     unsigned char* byte_stream = img->bits();
     double* arithmetic_stream = NULL;

     if(runlength)  byte_stream = runlength_encode(byte_stream, &numBytes);
     if(huffman)    byte_stream = huffman_encode(byte_stream, &numBytes);
     if(arithmetic) arithmetic_stream = arithmetic_encode(byte_stream, &numBytes);

     FILE* output;
     if(!(output = fopen(filename.toStdString().c_str(), "w"))) { return; }
     fprintf(output, "%d %d %d %lu", mode, width, height, numBytes);
     if(!arithmetic)  fwrite(byte_stream, sizeof(unsigned char), numBytes, output);
     else             fwrite(arithmetic_stream, sizeof(double), numBytes, output);
     fclose(output);
}
```

Compression



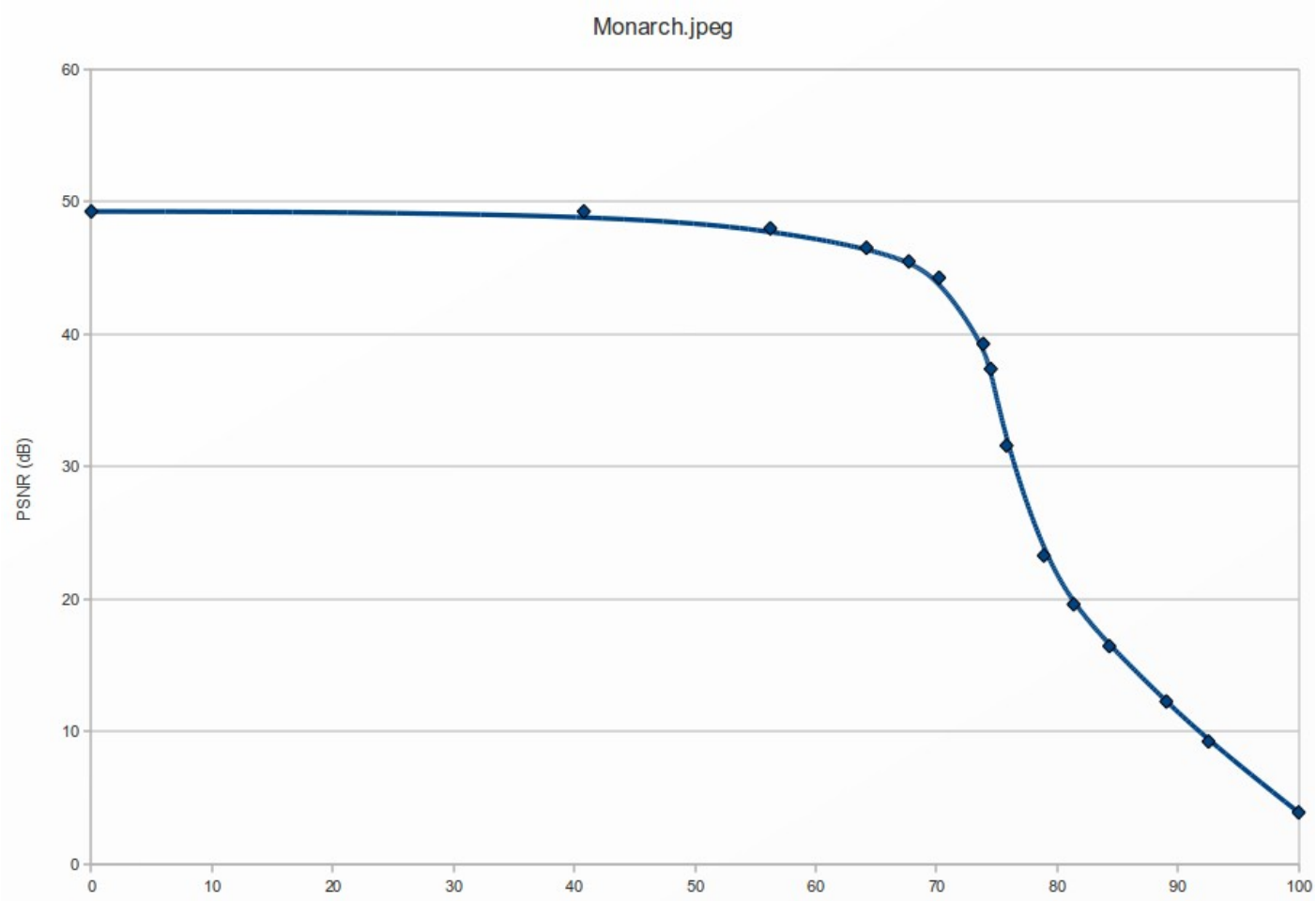
Discrete 9/7 Wavelet Transform, lifting implementation

- Used Grigory Pau's implementation, uses exact coefficients given by Taubman and Marcellin in JPEG2000 paper

  (http://www.embl.de/~gpau/misc/dwt97.c)

- CPU: lightly modified, GPU: heavily modified
- No color transform, still have to sort out colors
- One level transform
- Use piecewise continuous function to approximate threshold for zeroing out coefficients give a desired percent of coefficients zeroed out

Compression



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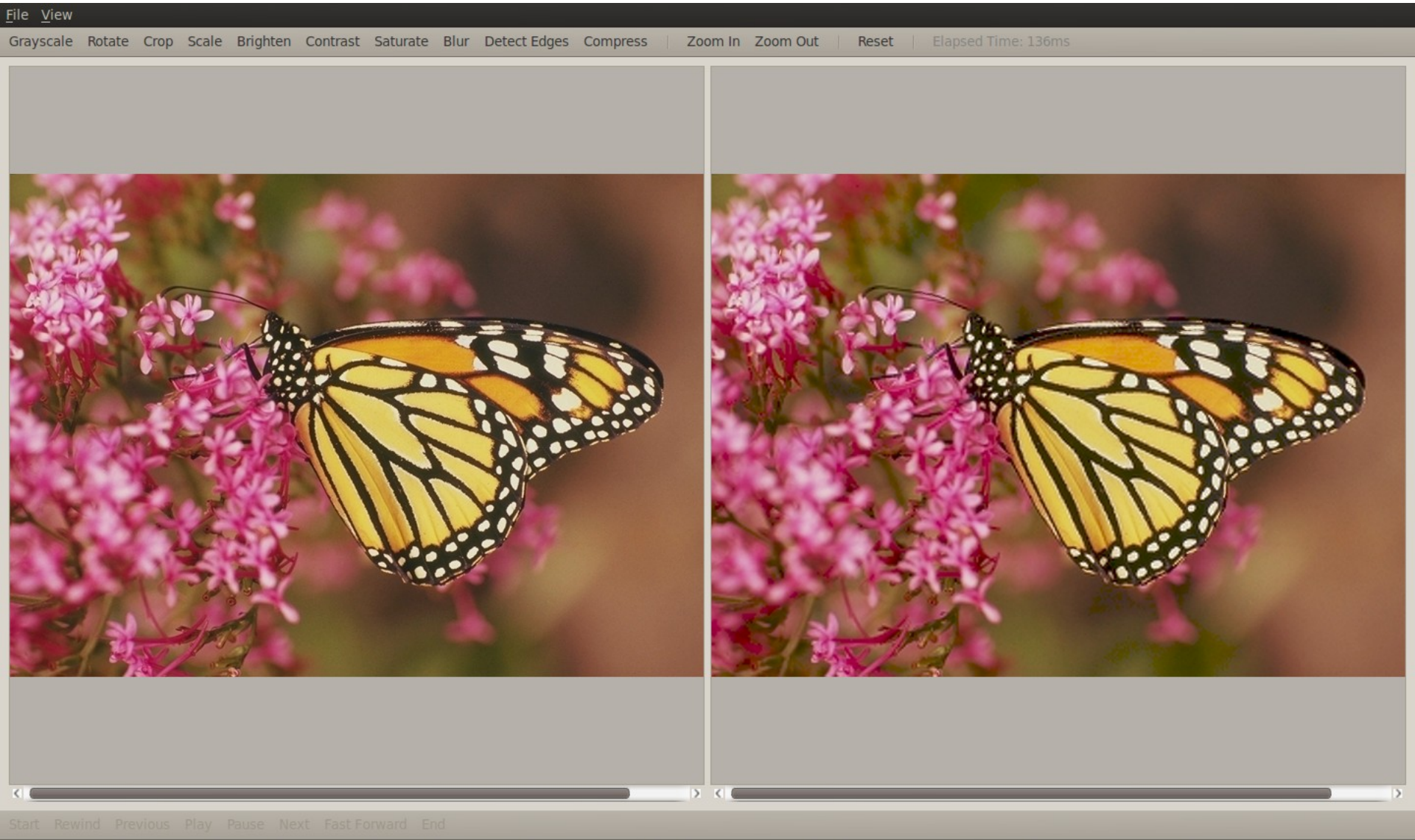
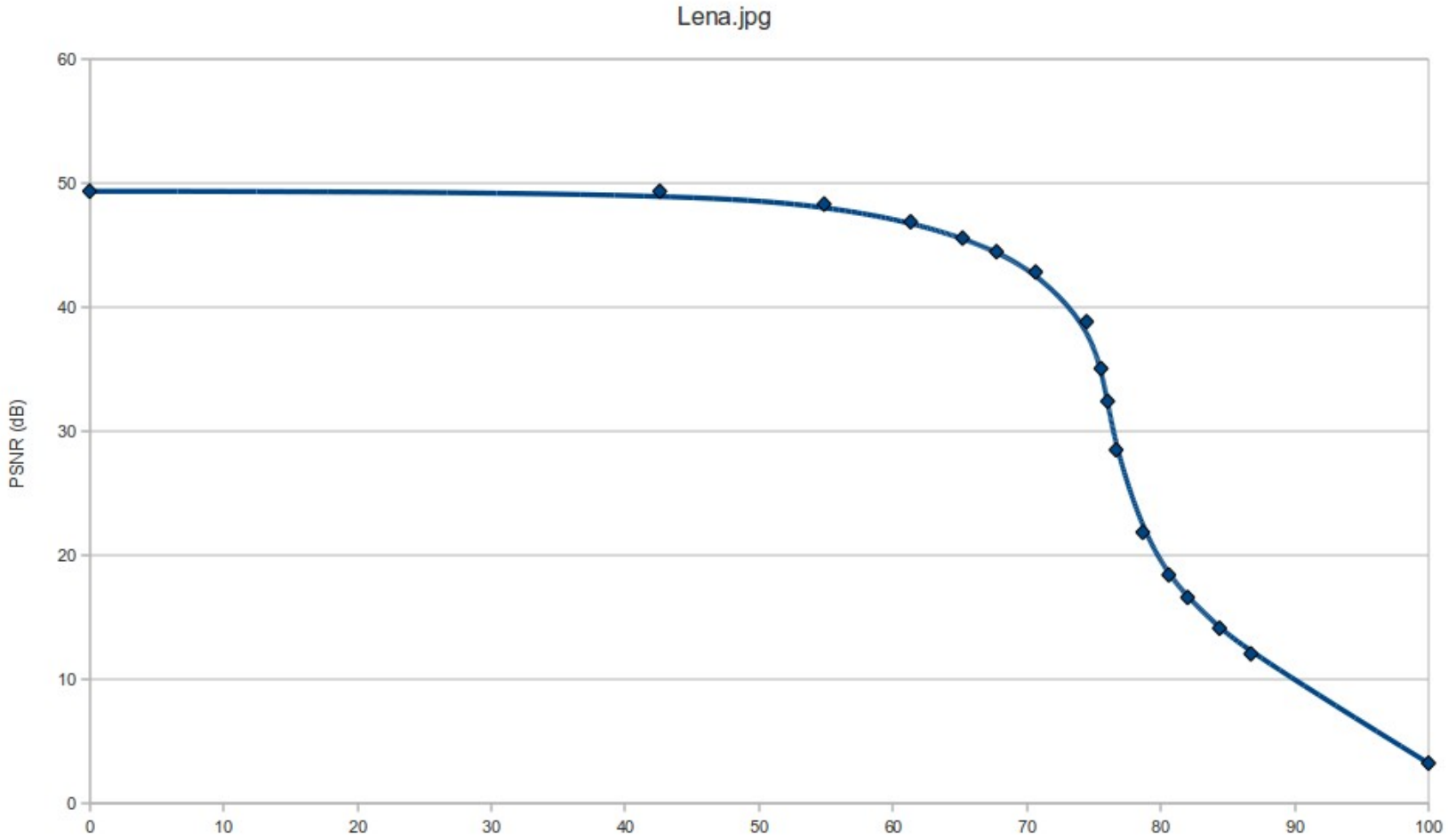
Compression



Compression



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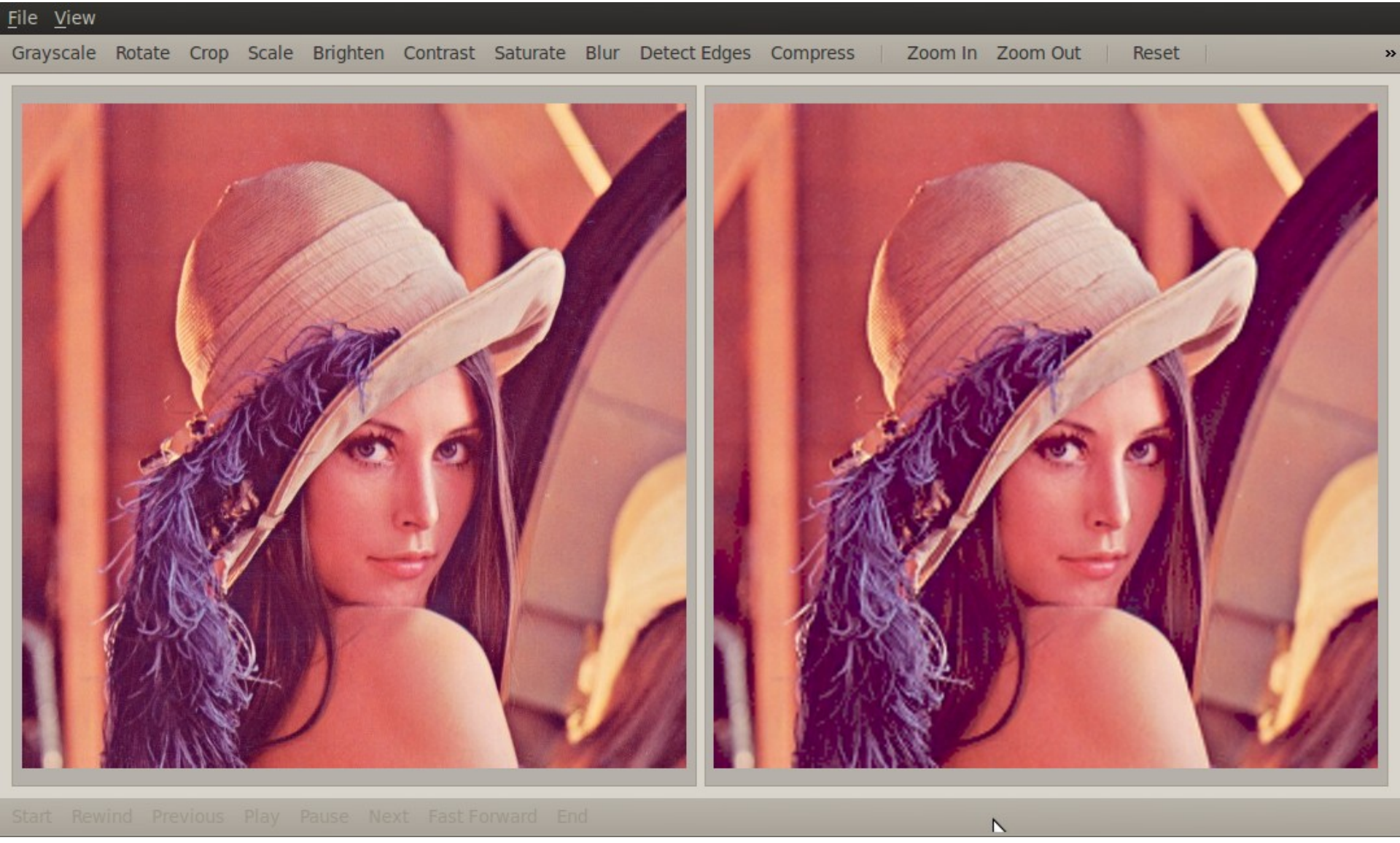
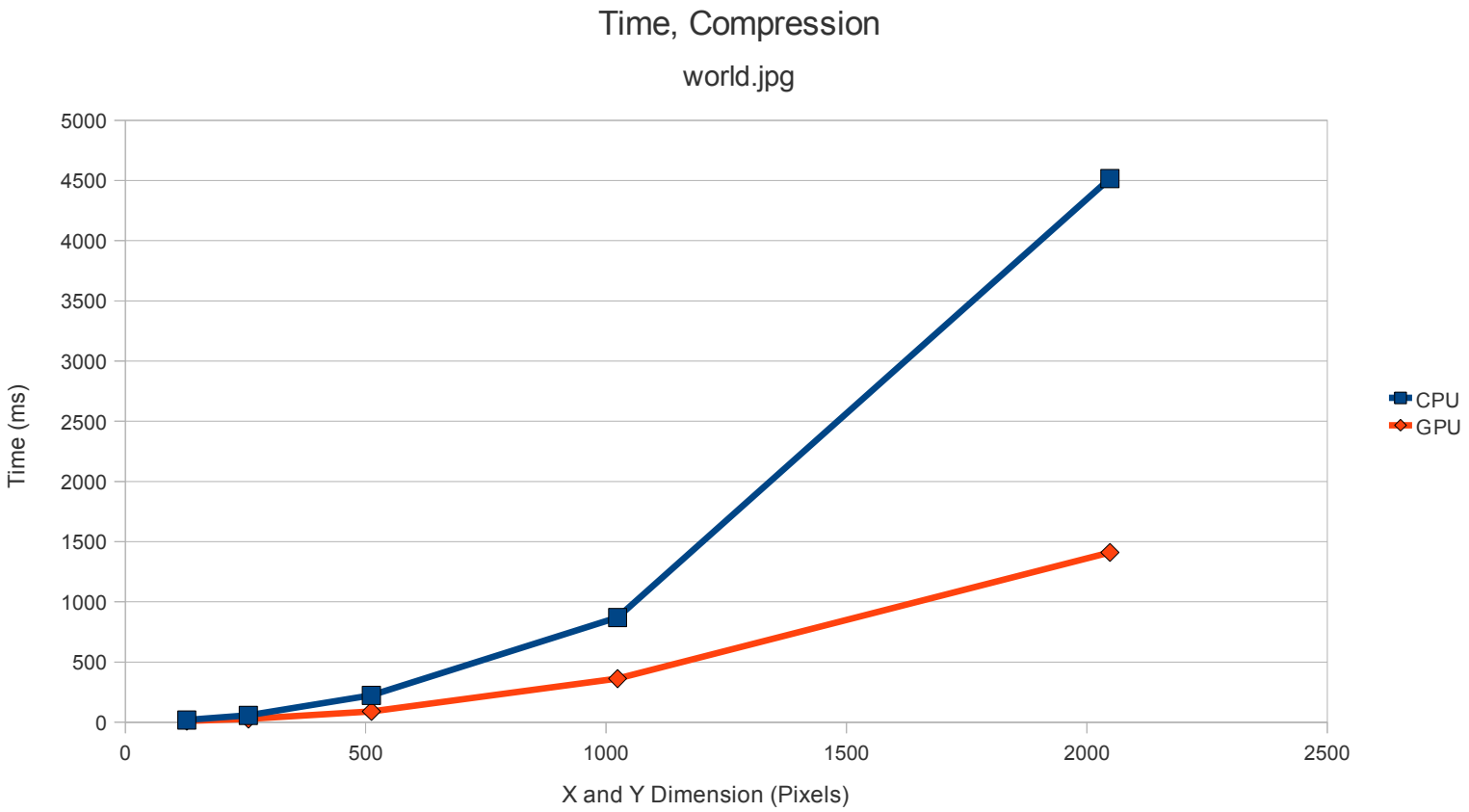
Compression



CPU vs GPU Speed Comparison



CPU vs GPU Speed Comparison

GPU Limitations:

- cudaMemcpy() still runs in linear time, necessary to move data onto and off of a GPU
- Resources used by operating system, failed to allocate space for a 4096x4096 image (64MB * 2)
- Wavelet transform doesn't use __shared__ memory

Questions?