Assignment 1: Transform Coding

CS 4600 Computer Graphics Fall 2018

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1. Audio Coding
   a. DCT

   According to Fig. 1, we can write code for DCT transform. Use for loop to sum.

$$F(u) = c(u) \sum_{i=0}^{N-1} cos\left(\frac{(2i+1)u\pi}{2N}\right) f(i),$$

Fig. 1

Code snippet

```
for (int u = 0; u < size; u++) {
    float sum = 0;
    for (int i = 0; i < size; i++) {
        sum += std::cos((2 * i + 1) * u * M_PI / 2 / size) * A[i];
    }
    C[u] = (u == 0 ? sqrtf(2) / 4 : 0.5) * sum;
}
```

Bug solved

Use 0.5 instead of ½ because integer arithmetic in C++ produces an integer which in this case would be 0.

   b. Compress

Because we do not really throw away data, so the last m data would only be wiped to zero.

Code snippet

```
for (int i = size - m; i < size; ++i) {
    C[i] = 0;
}
```

   c. Inverse DCT

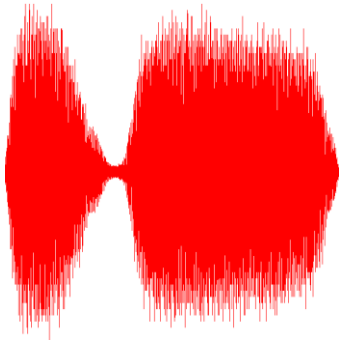
Same as DCT, we just write code according to the formula (Fig. 2).

$$f(i) = \sum_{u=0}^{N-1} c(u)\, cos\left(\frac{(2i+1)u\pi}{2N}\right) F(u)$$

Fig. 2

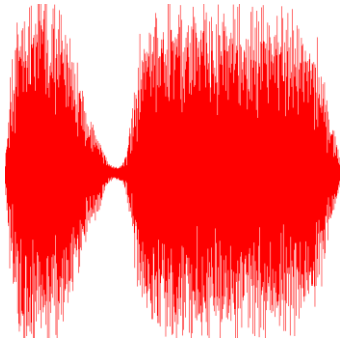
   d. Result

Original sound (m=0)



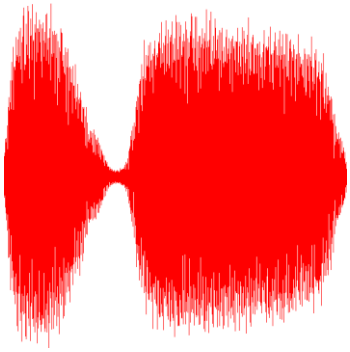
m=8 (max compression)

m=5 (required compression)



Wave shrinks. Sound is slightly distorted.

m=1 (min compression)



2. Image Coding

a. 2D DCT

Following the formula in Fig. 3, use for loop to sum the value.

$$F(u,v) = c(u)\,c(v) \sum_{x,y=0}^{N-1} \cos\left(\frac{(2x+1)u\pi}{2N}\right) \cos\left(\frac{(2y+1)v\pi}{2N}\right) f(x,y)$$

Fig. 3

Because the input array is not 2D, when using i and j to index elements, we need to convert 2D index to 1D index, as is shown in code.

Code snippet

```
for (int v = 0; v < blockSize; v++) {
    for (int u = 0; u < blockSize; u++) {
        int indexUV = v * blockSize + u;
        float sum = 0;
        for (int y = 0; y < blockSize; y++) {
            for (int x = 0; x < blockSize; x++) {
                int indexXY = y * blockSize + x;
                sum += std::cos((2 * x + 1) * u * M_PI / 2 / blockSize) * std::cos((2 * y + 1) * v * M_PI / 2 / blockSize)*A[indexXY];
            }
        }
        C[indexUV] = (u == 0 ? sqrtf(2) / 4 : 0.5f) * (v == 0 ? sqrtf(2) / 4 : 0.5f) * sum;
    }
}
```

b. Compress

Similar as 1D DCT but we will set some matrix elements to zero.

Code snippet

```
for (int i = 0; i < blockSize; i++) {
    for (int j = 0; j < blockSize; j++) {
        if (i + j ≤ m)
        {
            continue;
        }
        int index = i * blockSize + j;
        C[index] = 0;
    }
}
```

c. Inverse 2D DCT

Use the formula in Fig. 4.

$$f(x,y) = \sum_{u,v=0}^{N-1} c(u)\,c(v) \cos\left(\frac{(2x+1)u\pi}{2N}\right) \cos\left(\frac{(2y+1)v\pi}{2N}\right) F(u,v)$$

Fig. 4

Code snippet

```
for (int y = 0; y < blockSize; y++) {
    for (int x = 0; x < blockSize; x++) {
        int indexXY = y * blockSize + x;
        float sum = 0;
        for (int v = 0; v < blockSize; v++) {
            for (int u = 0; u < blockSize; u++) {
                int indexUV = v * blockSize + u;
                sum += (u == 0 ? sqrtf(2) / 4 : 0.5f) * (v == 0 ? sqrtf(2) / 4 : 0.5f)
                    * std::cos((2 * x + 1) * u * M_PI / 2 / blockSize)
                    * std::cos((2 * y + 1) * v * M_PI / 2 / blockSize)
                    *C[indexUV];
            }
        }
        B[indexXY] = sum;
    }
}
```

d. Result

Original photo

m = 1

m = 3

m=15

3. Reference
   CS 4600 Assignment 1.pdf