COMP 40 Laboratory: Getting started with image compression

Introduction

The new 'arith' project is all about testing. If you go slowly and test methodically, you will have an easy time of it. If you write a big pile of code before testing, debugging it will be NO FUN. This lab shows you *exactly* how to get started on testing. There is nothing to submit, but if you follow the instructions, you will finish most of your compressor quickly and easily. In next week's lab, we'll talk about the `Bitpack` module.

Plan of the lab

1. Review the instructions for HW4 (arith). You don't need to understand all the details yet, but you should have a general sense of the compression and decompression steps that will be performed. You should recognize them in the diagram in Figure 1 (page 4)
2. Design the `ppmdiff` program, specified below, which will allow you to compare two images programmatically. The `ppmdiff` program will help you test your compressor and decompressor. If you have questions about ppmdiff, check with the course staff before writing code.
3. Code and test `ppmdiff` here in the lab.
4. With the rest of your lab time, start building a trivial image transformer which goes from the top of Figure 1 (page 4) down to the third box and back up to the top again.
   (a) Read an image in PPM format
   (b) Trim to an even number of columns and rows
   (c) Convert from scaled integers to floating-point numbers

   Although your full image transformer will write and read compressed files to/from disk, we'll leave that step for later. For testing purposes, you'll have your program compress "part of the way ", and then immediately reverse the transformation. For this first step, you're only going as far as encoding into floating point numbers, so you immediately enter your decompression path and:

   (d) Convert from floating-point numbers to scaled integers
   (e) Write the image in PPM format
5. Use `ppmdiff` to make sure your image transformer works properly. (You can also confirm by using `display` on the images.)
6. Built a slightly more elaborate version of the transformer from step 4. The more elaborate transformer should add one more pair of transformations: conversion from RGB color space to $Y/P_R/P_B$ color space and back again.
7. Test the more elaborate transformer.

After completing these steps, you'll be well positioned to keep extending your image transformer until you eventually have a complete compressor and decompressor.

Specification of `ppmdiff`

Program `ppmdiff` takes two arguments on the command line. It writes to standard output a single number which is a measure of the difference between two input images. Each argument is the name of a PPM file. Optionally, one or the other argument (but not both) may be the C string `"-"`, which stands for standard input.

Here's what `ppmdiff` does:

- Both files are read into images I and I'. The width and height of I and I' should differ by at most 1; if the difference is larger, `ppmdiff` should print an error message to standard error and should print the number 1.0 to standard output.
- Assuming w and h represent the *smaller* of the two widths and heights, compute

$$E = \sqrt{\frac{\sum_{0 \le i < w} \sum_{0 \le j < h} (R_{ij} - R'_{ij})^2 + (G_{ij} - G'_{ij})^2 + (B_{ij} - B'_{ij})^2}{3 \times w \times h}}.$$

  where, for example, R_{ij} is the red pixel located at coordinate (i, j) of image I. The value E is the *root mean square difference* of the pixel values in the two images.
- Print E to standard output with four digits after the decimal point.

Reminders

- After reviewing all of the lab instructions, build and test your `ppmdiff` program
- Get a preliminary, limited function end-to-end (compress/decompress) ppmtrans solution working as quickly as possible. then improve it,incrementally.
- Compile insanely often. If you use Emacs, learn how to use the commands

  ```
  M-x compile
  C-x `
  ```

  which will take you straight to the place where errors occur.

  If you use Vim, learn to use the commands `:make` and `:cn`.

  For either editor, your "compile command" should be `sh compile`, not `make` or `make -k`.
- Every time you extend your transformer, run it and compare the results using `ppmdiff`.
- Every time you get a good answer with `ppmdiff`, run your code again with `valgrind`.

What to expect from `ppmdiff`

Two similar but not identical images have a difference of around 16%:

```
$ ppmdiff a.ppm b.ppm
  0.1656
```

Pictures that are not at all similar have a larger difference:

```
$ ppmdiff a.ppm c.ppm
  0.2628
```

And just taking a single image, compressing with JPEG, and decompressing it, can produce errors from 0.1% to 1.5% (sometimes as high as 2.5%):

```
$ cjpeg cc.ppm | djpeg | ppmdiff cc.ppm -
 0.0013
$ cjpeg gullfoss.ppm | djpeg | ppmdiff gullfoss.ppm -
 0.0165
```

The numbers above are artifically low, because the original images have *already* been compressed with JPEG, so what we're seeing is the *additional* error introduced on a later run. If we use JPEG to compress and decompress a lossless image like a PNG, we see a larger error of around 2.5%:

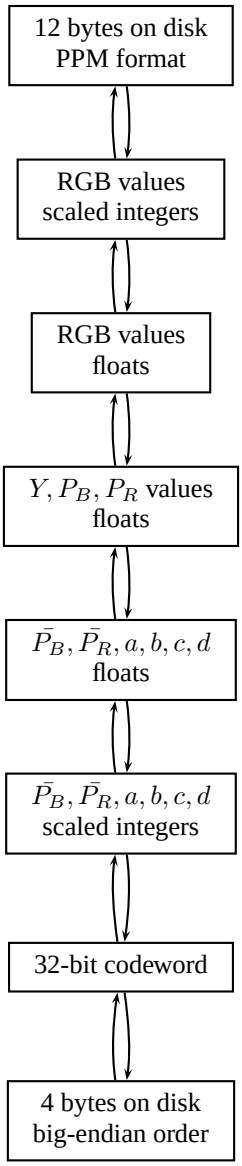
```
$ cjpeg qc.ppm | djpeg | ppmdiff qc.ppm -
 0.0255
```

On these kinds of images, the compressor you build should be competitive in quality with JPEG:

```
$ 40image -c qc.ppm | 40image -d | ppmdiff qc.ppm -
 0.0266

$ 40image -c cc.ppm | 40image -d | ppmdiff cc.ppm -
 0.0223

$ 40image -c gullfoss.ppm | 40image -d | ppmdiff gullfoss.ppm -
 0.0225
```



Compression goes from the top representation to the bottom representation. Decompression goes from the bottom representation back to the top representation.

Figure 1: Representations of a 2×2 block