WORKED EXAMPLE 4.2

Manipulating the Pixels in an Image

A digital image is made up of *pixels*. Each pixel is a tiny square of a given color. In this Worked Example, we will use a `Picture` type that has member functions for loading an image and accessing its pixels.

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Problem Statement Your task is to convert an image into its negative, turning white to black, cyan to red, and so on. The result is a negative image of the kind that old-fashioned film cameras used to produce.

Step 1 We provide you with a `Picture` type for manipulating images in the `.png` format. In order to use this type, you need to copy the files `picture.cpp`, `picture.h`, `lodepng.cpp`, and `lodepng.h` into the same folder as your source file, and you need to include them in the compilation. You can find these files in the `ch04/worked_example_2` folder of the companion code.

You also need to include the `picture.h` file into your source file, with the statement

```
#include "picture.h"
```

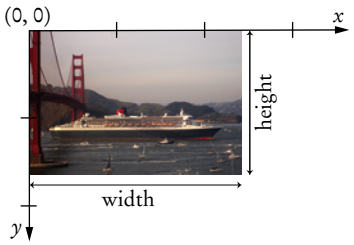
Note that the header file name, `picture.h`, is surrounded by quotation marks, not angle brackets, to indicate that you include a local file and not a system file.

To obtain a picture from a `.png` file, supply the file name like this:

```
Picture pic("queen-mary.png");
```

This statement defines a variable `pic` of type `Picture` that holds the pixels from the provided file.

Each pixel in the picture has an x- and y-coordinate, with $0 \le x <$ width and $0 \le y <$ height. The pixel with coordinates (0, 0) is in the top-left corner, and the y-axis points downward.



Each pixel has an RGB color value that is composed of the three primary colors: red, green, and blue. Each primary color amount is given as an integer between 0 (primary color not present) and 255 (maximum amount present). For example, a color with red value 255, green value 0, and blue value 255 is a bright purple color called magenta.

Step 2 Once you have a picture, you can call member functions to find out about the picture, or to modify it.

Here is what you can do:

- You can obtain the width and height of the picture by calling `pic.width()` and `pic.height()`.
- You can get the red, green, and blue values of a pixel at a particular location by calling `pic.red(x, y)`, `pic.green(x, y)`, and `pic.blue(x, y)`.
- You can set a pixel to any RGB color value by calling `pic.set(x, y, red, green, blue)`.
- You can save the changes to a file: `pic.save("result.png")`.
- You can add another picture to this picture—see Section 4.9.

Instead of loading a picture from an image file, you can also start with a monochromatic picture:

```
Picture all_magenta(300, 200, 255, 0, 255); // Specify width, height, and RGB color
```

Step 3 Now consider the task of converting an image into its negative.

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A pixel is turned into its negative like this:

```
int red = pic.red(x, y);
int green = pic.green(x, y);
int blue = pic.blue(x, y);
pic.set(x, y, 255 - red, 255 - green, 255 - blue);
```

We want to apply this operation to each pixel in the image. To process all pixels, we can use one of the following two strategies:

For each row
  For each pixel in the row
    Process the pixel.

or

For each column
  For each pixel in the column
    Process the pixel.

Because our pixel class uses x/y coordinates to access a pixel, it turns out to be more natural to use the second strategy. (In Chapter 6, you will encounter two-dimensional arrays that are accessed with row/column coordinates. In that situation, use the first form.)

To traverse each column, the x-coordinate starts at `0`. Because there are `pic.width()` columns, we use the loop

```
for (int x = 0; x < pic.width(); x++)
```

Once a column has been fixed, we need to traverse all y-coordinates in that column, starting from `0`. There are `pic.height()` rows, so our nested loops are

```
for (int x = 0; x < pic.width(); x++)
{
   for (int y = 0; y < pic.height(); y++)
   {
      . . .
   }
}
```

The following program solves our image manipulation problem:

worked_example_2/negative.cpp

```
#include "picture.h"

int main()
{
   Picture pic("queen-mary.png");

   for (int x = 0; x < pic.width(); x++)
   {
      for (int y = 0; y < pic.height(); y++)
      {
         int red = pic.red(x, y);
         int green = pic.green(x, y);
         int blue = pic.blue(x, y);
         pic.set(x, y, 255 - red, 255 - green, 255 - blue);
      }
   }
   pic.save("out.png");
   return 0;
}
```