Exercise Computer graphics

Bi-level display of gray-images

Exercise 12: (a) The following pattern is given for gray-level approximation:

```
16  5  6  7
15  4  1  8
14  3  2  9
13 12 11 10
```

A tiny image of 2x2 pixels is to be rendered using the above pattern. However, it is allowed to increase the resolution of the result by the factor of 4 for every side resulting in an output image of 8x8. Which pixels will be set in the output?

```
1  8
12 4
```

Solution:

```
.  .  .  .  .  *  *  *
.  .  *  .  .  *  *  *
.  .  .  .  .  *  *  .
.  .  .  .  .  .  .  .
.  *  *  *  .  .  .  .
.  *  *  *  .  *  *  .
.  *  *  *  .  *  *  .
.  *  *  *  .  .  .  .
```

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Exercise 12: (b) This time the following 8x4 image is to be rendered using the same pattern as before. However, this time the image size of 8x4 should be preserved using the modulo-technique. The rule is that a pixel will be set if the value in the pattern is smaller or equal to the gray level which should be displayed.

Hint:

In the modulo-version of the black & white rendering approach we first calculate the modulo of both the x- and the y-coordinate of a pixel. The result then addresses a grid in the pattern. We actually set the pixel only, if the value within the grid is smaller or equal to the gray-value to be rendered.

Example: We want to render gray value 11 of pixel (7, 4). The grid-cell in the pattern is (6 % 4, 3 % 4) = (2, 3) [first cell is (0,0)]. The grid-cell (2, 3) of the pattern is 11. Since 11 >= 11 we set the pixel.

Solution: (pixel set = *) / (pixel clear = .) / (fill out yourself = ?)

```
10  4 12 12 10  6  3  7      .  .  *  *  .  *  .  *
10  5 12 12  6 15  9 11      .  *  *  *  .  *  *  *
 8  9 12 12 12  4 10 15      .  *  *  *  .  *  *  *
 9 10  1  0  1  5 11  1      .  .  .  .  .  .  *  .
```

(Pattern)

```
16  5  6  7
15  4  1  8
14  3  2  9
13 12 11 10
```

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Exercise 12: (c) In exercise (a) a gray-value to be rendered was blown up by a factor according to the pattern. It is easy to imagine that this does not alter the mean gray value of the B/W image as compared to the original gray image.

Can you explain why this also holds true for exercise (b)? Here, one could argue that it is a matter of coincidence whether black or white is set because it mainly depends on the modulo.

Solution: An image consisting of a specific gray value would generate the same patter that is created by the dithering approach (without the modulo) increasing the image size.

An image consisting of black pixels and a single gray pixel would either result in an entirely back image or one with a white dot set (depending on the position of the gray pixel). So the dithered image would either be slightly too dark or too light.

Furthermore, an image could be designed, in which every gray value is slightly smaller than its corresponding value in the dithering matrix. So a medium gray image could result in a black approximation.

Conclusion: In general, the mean gray value can be guaranteed to be roughly preserved. But a slight deviation is very likely. However, a strong error like the one designed above is highly unlikely in either photos or generated images.