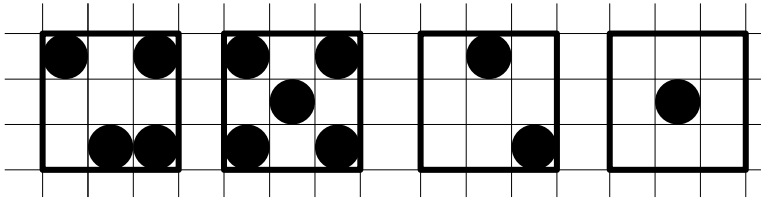
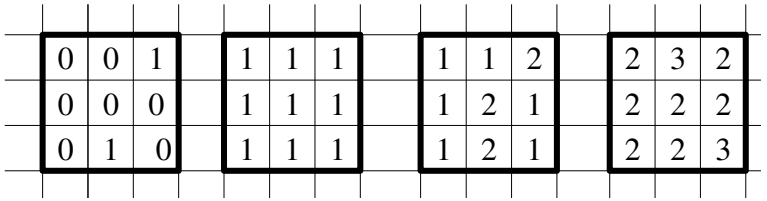
Exercise Computer graphics

Ordered dithering

Exercise 11: Ordered dithering meant that a gray value is approximated by different patterns like these:



For imaging devices being able to display a small number of gray levels, an extension was proposed that does not only consist of black and white pixels like shown above but that consists of shades of gray.



Explain how to use these gray-level patterns if the resolution of an image must not be increased.

Solution:

Like in the dithering example which only took black and white into account, our new dithering function expects the (x, y) coordinates and a gray value.

The gray value is used as an index that addresses one of the patterns shows in the lower left row. Gray value 20 would e. g., address the rightmost grid because its sum equals to 20.

The (x, y) coordinate addresses a specific element in the grid, e.g., (x % 3, y % 3) for 3x3 grids. The value in the grid cell will be returned and displayed. For gray value = 20 and (7, 6) the grid element (7 % 3, 6 % 3) = (1, 0) is addressed and its contained value 3 is returned.

Exercise Computer graphics

Bi-level display of gray-images

Exercise 12: (a) 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.

```
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
```

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

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

(Pattern)

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

Exercise Computer graphics

Bi-level display of gray-images

Exercise 12: (b)

The simplest approach to approximate gray levels is to replace each pixel of an image with gray values by an entire dithering patter if the resolution of the output device allows for that. This will obviously preserve the mean gray value of the original image.

Does this also hold true for the modulo approach in which to output resolution is equal to the resolution of the input image? Explain why.

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 likely. However, a strong error like the one designed above is highly unlikely in either photos or generated images.