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EXERCICIO 1

1. Qual a diferença entre convolução e correlação no contexto de imagens? O que são kernels e como eles influenciam o resultado da convolução?

Correlação:

A correlação mantém a orientação original do kernel, ou seja, não ocorre uma rotação do kernel. Isso significa que a correlação preserva as características direcionais do kernel. Geralmente, a correlação é usada para medir o grau de semelhança entre um padrão (representado pelo kernel) e diferentes partes da imagem. Na correlação, a resposta do filtro é sensível a pequenos deslocamentos do padrão na imagem. A correlação é frequentemente usada em aplicações de detecção de padrões, onde estamos interessados na identificação de regiões na imagem que correspondem ao padrão representado pelo kernel.

Convolução:

A convolução resulta em uma rotação de 180° do kernel antes de aplicá-lo à imagem. Isso significa que a convolução reflete o kernel antes de aplicá-lo à imagem. A convolução é amplamente utilizada em filtragem de imagem, onde o kernel atua como um filtro para suavizar, realçar ou extrair características específicas da imagem.

Convolução e Correlação: Filtros simétricos como o filtro gaussiano produzem resultados praticamente idênticos na convolução e correlação, pois a simetria do kernel anula o efeito de espelhamento.

Resposta para o que são kernels e como eles influenciam o resultado da convolução?

Kernels são pequenas matrizes de números utilizadas para aplicar efeitos ou extração de características em imagens.

Definição: Um kernel é uma matriz (tipicamente de tamanho 3x3, 5x5, etc.) que define um conjunto de pesos aplicados aos pixels de uma imagem.

Função: O kernel percorre a imagem, aplicando sua operação em cada região (ou janela) correspondente de pixels da imagem original.

Detecção de bordas: Um kernel pode ser configurado para realçar bordas, identificando mudanças abruptas na intensidade dos pixels.

Suavização: Um kernel de suavização pode ser usado para desfocar uma imagem, reduzindo o ruído.

Realce: Alguns kernels podem aumentar a nitidez de uma imagem.

EXERCICIO 2

a) Dê a convolução dos dois (w $\star f$).

Passo 1: dada a matriz f, aplicar o 0 padding:

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Passo 2: dado o kernel, inverte-lo: Matriz $kernel$:

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

invertendo:

Matriz $kernel\_invertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

Passo 3: para ir aplicando o calculo (calculo da convolucao) na matriz:

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &1 \times 4 + 0 \times 8 + 0 \times 4 + \\ &0 \times 4 + 1 \times 8 + 1 \times 4 + \\ &\quad 0 \times 2 + 1 \times 4 + 0 \times 2 = 16 \end{aligned}$$

$$\begin{bmatrix} 16 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 0 \times 8 + 0 \times 4 + \\ &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &\quad 1 \times 2 + 0 \times 4 + 1 \times 2 = 20 \end{aligned}$$

$$\begin{bmatrix} 16 & 20 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 0 \times 8 + 0 \times 4 + \\ &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &\quad 0 \times 2 + 1 \times 4 + 0 \times 2 = 20 \end{aligned}$$

Tabela 3

$$\begin{bmatrix} 16 & 20 & 20 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 0 \times 8 + 0 \times 4 + \\ &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &\quad 0 \times 2 + 1 \times 4 + 0 \times 2 = 20 \end{aligned}$$

Tabela 4

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$0 \times 4 + 0 \times 8 + 0 \times 4 +$$
$$1 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$0 \times 2 + 1 \times 4 + 0 \times 2 = 16$$

Tabela 5

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 16 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$0 \times 4 + 1 \times 8 + 1 \times 4 +$$
$$0 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$0 \times 2 + 1 \times 4 + 0 \times 2 = 24$$

Tabela 6

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 16 \\ 24 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

KernelIvertido:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &1 \times 4 + 0 \times 8 + 1 \times 4 + \\ &1 \times 2 + 0 \times 4 + 1 \times 2 = 28 \end{aligned}$$

Tabela 7

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 16 \\ 24 & 28 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

KernelIvertido:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &0 \times 2 + 1 \times 4 + 0 \times 2 = 28 \end{aligned}$$

Tabela 8

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 16 \\ 24 & 28 & 28 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$1 \times 4 + 1 \times 8 + 1 \times 4 +$$
$$1 \times 4 + 0 \times 8 + 1 \times 4 +$$
$$1 \times 2 + 0 \times 4 + 1 \times 2 = 28$$

Tabela 9

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$1 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$0 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$0 \times 2 + 1 \times 4 + 0 \times 2 = 28$$

Tabela 10

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &0 \times 2 + 1 \times 4 + 0 \times 2 = 20 \end{aligned}$$

Tabela 11

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$1 \times 4 + 0 \times 8 + 1 \times 4 +$$
$$1 \times 4 + 0 \times 8 + 1 \times 4 +$$
$$1 \times 2 + 0 \times 4 + 1 \times 2 = 20$$

Tabela 12

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$0 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$0 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$0 \times 2 + 1 \times 4 + 0 \times 2 = 20$$

Tabela 13

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &1 \times 4 + 0 \times 8 + 1 \times 4 + \\ &1 \times 4 + 0 \times 8 + 1 \times 4 + \\ &1 \times 2 + 0 \times 4 + 1 \times 2 = 20 \end{aligned}$$

Tabela 14

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &0 \times 2 + 1 \times 4 + 0 \times 2 = 20 \end{aligned}$$

Tabela 15

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &0 \times 2 + 1 \times 4 + 1 \times 2 = 22 \end{aligned}$$

Tabela 16

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &1 \times 4 + 0 \times 8 + 1 \times 4 + \\ &1 \times 4 + 0 \times 8 + 1 \times 4 + \\ &1 \times 2 + 1 \times 4 + 1 \times 2 = 24 \end{aligned}$$

Tabela 17

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 0 \times 8 + 0 \times 4 + \\ &0 \times 4 + 0 \times 8 + 0 \times 4 + \\ &1 \times 2 + 1 \times 4 + 1 \times 2 = 24 \end{aligned}$$

Tabela 18

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$1 \times 4 + 0 \times 8 + 1 \times 4 +$$
$$1 \times 4 + 0 \times 8 + 1 \times 4 +$$
$$1 \times 2 + 1 \times 4 + 1 \times 2 = 24$$

Tabela 19

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 24 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$0 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$0 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$1 \times 2 + 1 \times 4 + 0 \times 2 = 22$$

Tabela 20

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 24 & 22 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &0 \times 4 + 1 \times 8 + 1 \times 4 + \\ &0 \times 2 + 0 \times 4 + 0 \times 2 = 20 \end{aligned}$$

Tabela 21

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 24 & 22 \\ 20 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &1 \times 4 + 0 \times 8 + 1 \times 4 + \\ &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &0 \times 2 + 0 \times 4 + 0 \times 2 = 24 \end{aligned}$$

Tabela 22

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 24 & 22 \\ 20 & 24 & 0 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 1 \times 8 + 0 \times 4 + \\ &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &0 \times 2 + 0 \times 4 + 0 \times 2 = 24 \end{aligned}$$

Tabela 23

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 24 & 22 \\ 20 & 24 & 24 & 0 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$\begin{aligned} &1 \times 4 + 0 \times 8 + 1 \times 4 + \\ &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &0 \times 2 + 0 \times 4 + 0 \times 2 = 24 \end{aligned}$$

Tabela 24

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 24 & 22 \\ 20 & 24 & 24 & 24 & 0 \end{bmatrix}$$

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Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$KernelIvertido$:

$$\begin{bmatrix} 4 & 8 & 4 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

$$1 \times 4 + 0 \times 8 + 1 \times 4 +$$
$$1 \times 4 + 1 \times 8 + 1 \times 4 +$$
$$0 \times 2 + 0 \times 4 + 0 \times 2 = 24$$

Tabela 25

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 24 & 22 \\ 20 & 24 & 24 & 24 & 20 \end{bmatrix}$$

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Resultado da operacao de convolucao:

$$\begin{bmatrix} 16 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 28 \\ 20 & 20 & 20 & 20 & 20 \\ 22 & 24 & 24 & 24 & 22 \\ 20 & 24 & 24 & 24 & 20 \end{bmatrix}$$

b. Calcule a correlação com a imagem f (w f).
Dado a matriz:

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

e o kernel:

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Aplicando a correlacao (correlacao) temos:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 0 \times 8 + 0 \times 4 + \\ &0 \times 4 + 1 \times 8 + 1 \times 4 + \\ &\quad 0 \times 2 + 1 \times 4 + 0 \times 2 = 20 \end{aligned}$$

Tabela 1

$$\begin{bmatrix} 20 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

==========

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 0 \times 8 + 0 \times 4 + \\ &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &1 \times 2 + 0 \times 4 + 1 \times 2 = 24 \end{aligned}$$

Tabela 2
$$\begin{bmatrix} 20 & 24 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

==========

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

$$\begin{aligned} &0 \times 4 + 0 \times 8 + 0 \times 4 + \\ &1 \times 4 + 1 \times 8 + 1 \times 4 + \\ &0 \times 2 + 1 \times 4 + 0 \times 2 = 24 \end{aligned}$$

Tabela 3
$$\begin{bmatrix} 20 & 24 & 24 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

$$0 \times 4 + 0 \times 8 + 0 \times 4 +$$
$$1 \times 4 + 1 \times 8 + 1 \times 4 +$$
$$1 \times 2 + 0 \times 4 + 1 \times 2 = 24$$

Tabela 4
$$\begin{bmatrix} 20 & 24 & 24 & 24 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

==========

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

$$0 \times 4 + 0 \times 8 + 0 \times 4 +$$
$$1 \times 4 + 1 \times 8 + 0 \times 4 +$$
$$0 \times 2 + 1 \times 4 + 0 \times 2 = 24$$

Tabela 5
$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz

f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 6
$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz

f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 7
$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz

f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 8 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 9 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

==========

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 10 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

==========

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 11

$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 12

$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 13 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 14 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 15 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 16
$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 17
$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

==========

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 18 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

==========

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 19 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 20 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 24 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

==========

Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 21
$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 24 \\ 16 & 0 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 22
$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 24 \\ 16 & 20 & 0 & 0 & 0 \end{bmatrix}$$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 23 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 24 \\ 16 & 20 & 20 & 0 & 0 \end{bmatrix}$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 24 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 24 \\ 16 & 20 & 20 & 20 & 0 \end{bmatrix}$

========== Matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 4 & 8 & 4 \end{bmatrix}$$

Tabela 25 $\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 24 \\ 16 & 20 & 20 & 20 & 16 \end{bmatrix}$

==========

Matriz Resultado Final da correlacao:

$$\begin{bmatrix} 20 & 24 & 24 & 24 & 24 \\ 22 & 24 & 24 & 24 & 24 \\ 20 & 20 & 20 & 20 & 20 \\ 24 & 28 & 28 & 28 & 24 \\ 16 & 20 & 20 & 20 & 16 \end{bmatrix}$$

EXERCICIO 3

Para resolver a questão, vamos seguir cada um dos itens a, b e c conforme solicitado.

Item a: Filtro da Média com Kernel 3x3

Primeiro, vamos aplicar um filtro da média usando um kernel 3x3 diferente dos mencionados no livro. Podemos escolher o seguinte kernel de média:

$$\text{Kernel de média} = \frac{1}{9}\begin{bmatrix} 2 & 2 & 2 \\ 2 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix}$$

Aplicação do Kernel de Média

Kernel e Função f

Dado o kernel:

$$\begin{bmatrix} 2 & 2 & 2 \\ 2 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix}$$

Dado a função f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 10 & 10 & 25 & 10 & 10 & 0 \\ 0 & 10 & 0 & 12 & 0 & 10 & 0 \\ 0 & 25 & 0 & 12 & 0 & 25 & 0 \\ 0 & 10 & 0 & 12 & 0 & 10 & 0 \\ 0 & 10 & 10 & 25 & 10 & 10 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Teremos o seguinte resultado usando filtro de média:

Tabela 1

$$\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0 = 6.6667$$

$$\begin{bmatrix} 6.6667 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 2

$$\frac{1}{9}\times 2\times 12+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 25+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0 = 14.8889$$

Resultado:

$$\begin{bmatrix} 6.6667 & 14.8889 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 3

$$\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 12+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 25+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0 = 12.6667$$

Resultado:

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 4

$$\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 12+\frac{1}{9}\times\frac{1}{9}\times 2\times 10+\frac{1}{9}\times\frac{1}{9}\times 2\times 10+\frac{1}{9}\times\frac{1}{9}\times 2\times 25+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0 = 14.8889$$

Resultado:

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 5

$$2\times 0+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0 = 6.6667$$

Resultado:

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 6

$$2\times 0+\frac{1}{9}\times 2\times 25+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 10+\frac{1}{9}\times 2\times 0 = 12.2222$$

Resultado:

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 7

$$2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10=23.1111$$

Resultado:

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 8

$$2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times10=15.3333$$

Resultado:

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 9

$$2\times25+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times25=23.1111$$

Resultado:

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 10

$$2\times0+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10=12.2222$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 11

$$2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0=10.0$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 12

$$2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10 = 18.0$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 13

$$2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0 = 8.0$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 14

$$2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12 = 18.0$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 15

$$2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0 = 10.0$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 16

$$2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times0=12.2222$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 17

$$2\times25+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times25=23.1111$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 18

$$2\times10+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0=15.3333$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 19

$$2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12=23.1111$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 20

$$2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times0=12.2222$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 21

$$2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0=6.6667$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 6.6667 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 22

$$2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10=14.8889$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 6.6667 & 14.8889 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 23

$$2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12+\frac{1}{9}\times2\times0=12.6667$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 6.6667 & 14.8889 & 12.6667 & 0 & 0 \end{bmatrix}$$

Tabela 24

$$2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times25+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times12=14.8889$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 6.6667 & 14.8889 & 12.6667 & 14.8889 & 0 \end{bmatrix}$$

Tabela 25

$$2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0+\frac{1}{9}\times2\times10+\frac{1}{9}\times2\times0 = 6.6667$$

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \end{bmatrix}$$

Resultado do filtro de média

$$\begin{bmatrix} 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 10.0 & 18.0 & 8.0 & 18.0 & 10.0 \\ 12.2222 & 23.1111 & 15.3333 & 23.1111 & 12.2222 \\ 6.6667 & 14.8889 & 12.6667 & 14.8889 & 6.6667 \end{bmatrix}$$

Item b: Sharpening com Kernel 3x3
Para o sharpening, podemos usar o kernel fornecido w:

$$w = \begin{bmatrix} 2 & 2 & 2 \\ 2 & 10 & 2 \\ 2 & 2 & 2 \end{bmatrix}$$

Aplicação do Kernel de Sharpening
Dado o kernel:

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & -5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Dada a matriz f:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 10 & 10 & 25 & 10 & 10 & 0 \\ 0 & 10 & 0 & 12 & 0 & 10 & 0 \\ 0 & 25 & 0 & 12 & 0 & 25 & 0 \\ 0 & 10 & 0 & 12 & 0 & 10 & 0 \\ 0 & 10 & 10 & 25 & 10 & 10 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Os resultados usando filtro de média são:

Tabela 1

$$= -70$$

$$\begin{bmatrix} -70 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

==========

Tabela 2

$$= -85$$

$$\begin{bmatrix} -70 & -85 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

==========

Tabela 3

$$= -157$$

$$\begin{bmatrix} -70 & -85 & -157 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

==========

Tabela 4

$$= -85$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

==========

Tabela 5

$$= -70$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

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Tabela 6

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 25 & + \\ 0 & x & 0 & + \\ -1 & x & 0 & + \\ -5 & x & 10 & + \\ -1 & x & 0 & + \\ 0 & x & 10 & + \\ -1 & x & 10 & + \\ 0 & x & 0 & + \end{bmatrix} = -85$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 7

$$\begin{bmatrix} 0 & x & 12 & + \\ -1 & x & 0 & + \\ 0 & x & 25 & + \\ -1 & x & 12 & + \\ -5 & x & 0 & + \\ -1 & x & 10 & + \\ 0 & x & 25 & + \\ -1 & x & 10 & + \\ 0 & x & 10 & + \end{bmatrix} = -32$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 8

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 12 & + \\ 0 & x & 0 & + \\ -1 & x & 0 & + \\ -5 & x & 12 & + \\ -1 & x & 0 & + \\ 0 & x & 10 & + \\ -1 & x & 25 & + \\ 0 & x & 10 & + \end{bmatrix} = -97$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 9

$$\begin{bmatrix} 0 & x & 25 & + \\ -1 & x & 0 & + \\ 0 & x & 12 & + \\ -1 & x & 10 & + \\ -5 & x & 0 & + \\ -1 & x & 12 & + \\ 0 & x & 10 & + \\ -1 & x & 10 & + \\ 0 & x & 25 & + \end{bmatrix} = -32$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 10

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 25 & + \\ 0 & x & 0 & + \\ -1 & x & 0 & + \\ -5 & x & 10 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 10 & + \\ 0 & x & 10 & + \end{bmatrix} = -85$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 12

$$\begin{bmatrix} 0 & x & 12 & + \\ -1 & x & 0 & + \\ 0 & x & 10 & + \\ -1 & x & 12 & + \\ -5 & x & 0 & + \\ -1 & x & 25 & + \\ 0 & x & 12 & + \\ -1 & x & 0 & + \\ 0 & x & 10 & + \end{bmatrix} = -37$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 13

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 12 & + \\ 0 & x & 0 & + \\ -1 & x & 0 & + \\ -5 & x & 12 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 12 & + \\ 0 & x & 0 & + \end{bmatrix} = -84$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 14

$$\begin{bmatrix} 0 & x & 10 & + \\ -1 & x & 0 & + \\ 0 & x & 12 & + \\ -1 & x & 25 & + \\ -5 & x & 0 & + \\ -1 & x & 12 & + \\ 0 & x & 10 & + \\ -1 & x & 0 & + \\ 0 & x & 12 & + \end{bmatrix} = -37$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 15

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 10 & + \\ 0 & x & 0 & + \\ -1 & x & 0 & + \\ -5 & x & 25 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 10 & + \\ 0 & x & 0 & + \end{bmatrix} = -145$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 16

$$\begin{bmatrix} 0 & x & 10 & + \\ -1 & x & 10 & + \\ 0 & x & 0 & + \\ -1 & x & 0 & + \\ -5 & x & 10 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 25 & + \\ 0 & x & 0 & + \end{bmatrix} = -85$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 17

$$\begin{bmatrix} 0 & x & 25 & + \\ -1 & x & 10 & + \\ 0 & x & 10 & + \\ -1 & x & 12 & + \\ -5 & x & 0 & + \\ -1 & x & 10 & + \\ 0 & x & 12 & + \\ -1 & x & 0 & + \\ 0 & x & 25 & + \end{bmatrix} = -32$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 18

$$\begin{bmatrix} 0 & x & 10 & + \\ -1 & x & 25 & + \\ 0 & x & 10 & + \\ -1 & x & 0 & + \\ -5 & x & 12 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 12 & + \\ 0 & x & 0 & + \end{bmatrix} = -97$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 19

$$\begin{bmatrix} 0 & x & 10 & + \\ -1 & x & 10 & + \\ 0 & x & 25 & + \\ -1 & x & 10 & + \\ -5 & x & 0 & + \\ -1 & x & 12 & + \\ 0 & x & 25 & + \\ -1 & x & 0 & + \\ 0 & x & 12 & + \end{bmatrix} = -32$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & -32 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 20

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 10 & + \\ 0 & x & 10 & + \\ -1 & x & 0 & + \\ -5 & x & 10 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 25 & + \\ 0 & x & 0 & + \end{bmatrix} = -85$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & -32 & -85 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 21

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 10 & + \\ -5 & x & 10 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 10 & + \\ 0 & x & 0 & + \end{bmatrix} = -70$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & -32 & -85 \\ -70 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 22

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 25 & + \\ -5 & x & 10 & + \\ -1 & x & 10 & + \\ 0 & x & 12 & + \\ -1 & x & 0 & + \\ 0 & x & 10 & + \end{bmatrix} = -85$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & -32 & -85 \\ -70 & -85 & 0 & 0 & 0 \end{bmatrix}$$

Tabela 23

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 10 & + \\ -5 & x & 25 & + \\ -1 & x & 10 & + \\ 0 & x & 0 & + \\ -1 & x & 12 & + \\ 0 & x & 0 & + \end{bmatrix} = -157$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & -32 & -85 \\ -70 & -85 & -157 & 0 & 0 \end{bmatrix}$$

Tabela 24

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 10 & + \\ -5 & x & 10 & + \\ -1 & x & 25 & + \\ 0 & x & 10 & + \\ -1 & x & 0 & + \\ 0 & x & 12 & + \end{bmatrix} = -85$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & -32 & -85 \\ -70 & -85 & -157 & -85 & 0 \end{bmatrix}$$

Tabela 25

$$\begin{bmatrix} 0 & x & 0 & + \\ -1 & x & 0 & + \\ 0 & x & 0 & + \\ -1 & x & 0 & + \\ -5 & x & 10 & + \\ -1 & x & 10 & + \\ 0 & x & 0 & + \\ -1 & x & 10 & + \\ 0 & x & 0 & + \end{bmatrix} = -70$$

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & -32 & -85 \\ -70 & -85 & -157 & -85 & -70 \end{bmatrix}$$

Resultado sharpening:

$$\begin{bmatrix} -70 & -85 & -157 & -85 & -70 \\ -85 & -32 & -97 & -32 & -85 \\ -145 & -37 & -84 & -37 & -145 \\ -85 & -32 & -97 & -32 & -85 \\ -70 & -85 & -157 & -85 & -70 \end{bmatrix}$$

Item c: Discussão dos Resultados

Filtro da Média

O filtro da média suaviza a imagem, reduzindo o ruído e borrando os detalhes. Isso ocorre porque cada pixel é substituído pela média de seus vizinhos, o que tende a atenuar variações bruscas de intensidade. No entanto, esse filtro também pode diminuir a nitidez de bordas e detalhes importantes na imagem.

Sharpening

O sharpening, por outro lado, realça as bordas e detalhes na imagem. Isso é conseguido aumentando a contribuição do pixel central na convolução, o que amplifica as diferenças de intensidade em torno das bordas. No entanto, um kernel de sharpening mal escolhido pode introduzir artefatos ou realçar o ruído presente na imagem.

Conclusão

Usando os kernels escolhidos, podemos ver que o filtro da média proporcionou uma imagem suavizada, enquanto o kernel de sharpening destacou mais as bordas e os detalhes, aumentando a nitidez da imagem.

EXERCICIO 4

a)

Kernel w:

$$w = \begin{pmatrix} 1 & 3 & 1 \\ 2 & 6 & 2 \\ 4 & 12 & 4 \end{pmatrix}$$

Calculando w_1 e w_2 tais que $w = w_1 * w_2$:

$w = w_1 \cdot w_2^T$, onde w_1 e w_2 são vetores coluna.

Seja $w_1 = \begin{pmatrix} 1 \\ 2 \\ 4 \end{pmatrix}$.

Para encontrar w_2, usamos a matriz original w e o vetor w_1:

$$\begin{pmatrix} 1 & 3 & 1 \\ 2 & 6 & 2 \\ 4 & 12 & 4 \end{pmatrix} = \begin{pmatrix} 1 \\ 2 \\ 4 \end{pmatrix} \cdot \begin{pmatrix} a & b & c \end{pmatrix}$$

Para encontrar os valores de a, b e c:

Pela primeira linha da matriz w:

$$1 = 1 \cdot a \implies a = 1$$

$$3 = 1 \cdot b \implies b = 3$$

$$1 = 1 \cdot c \implies c = 1$$

Pela segunda linha da matriz w:

$$2 = 2 \cdot a \implies a = 1$$

$$6 = 2 \cdot b \implies b = 3$$

$$2 = 2 \cdot c \implies c = 1$$

Pela terceira linha da matriz w:

$$4 = 4 \cdot a \implies a = 1$$

$$12 = 4 \cdot b \implies b = 3$$

$$4 = 4 \cdot c \implies c = 1$$

Então, $w_2 = \begin{pmatrix} 1 \\ 3 \\ 1 \end{pmatrix}$.

Logo, os vetores w_1 e w_2 são:

$$w_1 = \begin{pmatrix} 1 \\ 2 \\ 4 \end{pmatrix}, \quad w_2 = \begin{pmatrix} 1 & 3 & 1 \end{pmatrix}$$

Verificando a solucao temos w_1 e w_2:

$$\begin{pmatrix} 1 \\ 2 \\ 4 \end{pmatrix} \quad * \quad \begin{pmatrix} 1 & 3 & 1 \end{pmatrix} = \begin{pmatrix} 1 \cdot 1 & 1 \cdot 3 & 1 \cdot 1 \\ 2 \cdot 1 & 2 \cdot 3 & 2 \cdot 1 \\ 4 \cdot 1 & 4 \cdot 3 & 4 \cdot 1 \end{pmatrix}$$

$$w = \begin{pmatrix} 1 & 3 & 1 \\ 2 & 6 & 2 \\ 4 & 12 & 4 \end{pmatrix}$$