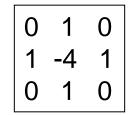
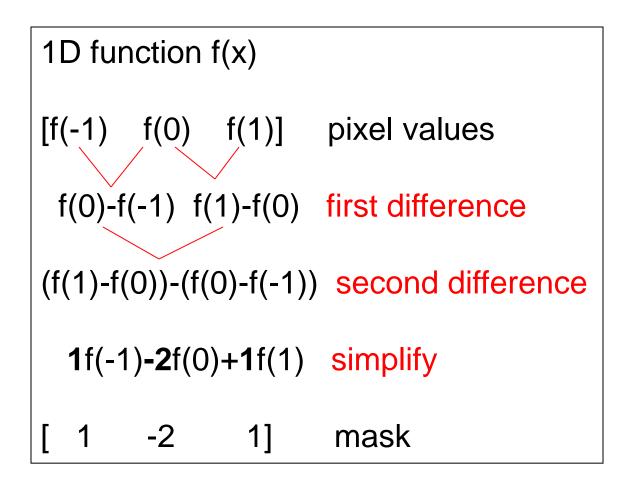
## How do we estimate the Second Derivative?

• Laplacian Filter:  $\nabla^2 f = \partial^2 f / \partial x^2 + \partial^2 f / \partial y^2$ 

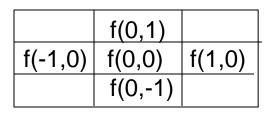


- Standard mask implementation
- Derivation: In 1D, the first derivative can be computed with mask [-1 0 1]
- The 1D second derivative is [1 -2 1]
- The Laplacian mask estimates the 2D second derivative.

## How did you get those masks?



## and in 2D



 $\partial f/\partial x(1/2) = f(1,0)-f(0,0)$  $\partial f/\partial x(-1/2) = f(0,0)-f(-1,0)$ 

 $\partial f / \partial x^2 = f(1,0) - 2f(0,0) + f(-1,0)$ 

 $\partial f/\partial y^2 = f(0,1)-2f(0,0)+f(0,-1)$ 

 $\begin{aligned} \nabla^2 f &= \partial f / \partial x^2 + \partial f / \partial y^2 \\ &= 1 f(1,0) - 4 f(0,0) + 1 f((-1,0) + 1 f(0,1) + 1 f(0,-1) \end{aligned}$