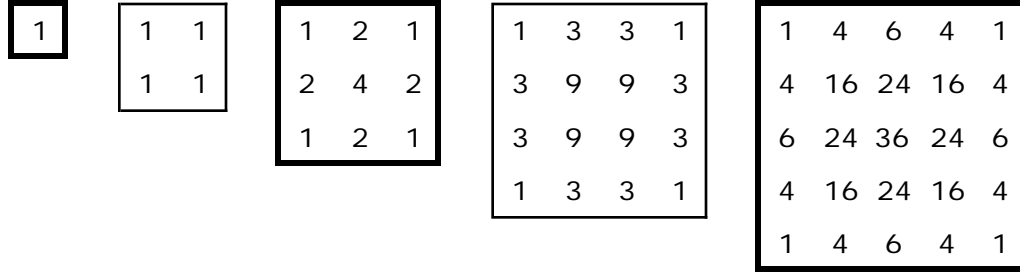


## APPENDICES

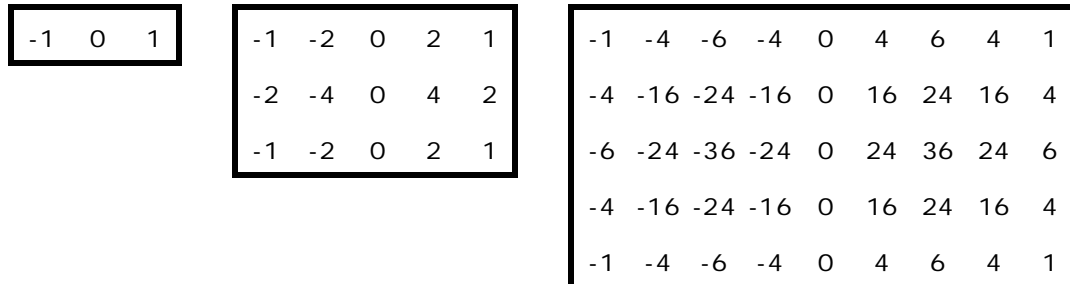
### Appendix A - Binomial Kernel and Difference of Gaussians Operator



**Fig. A.1** Results of applying binomial kernel in 2D, shown with dark outline after an even number of applications.

The binomial kernel is a 4x4 box filled with 1's in 2D (or an 8x8 cube in 3D). When applied repeatedly the results approximate the application of a Gaussian kernel by the Central Limit Theorem (see Fig. A.1). To keep the results centered, the kernel is applied twice, alternating the direction of displacement. Numbers shown in Fig. A.1 do not reflect normalization, which is accomplished by dividing by 4 after each iteration in 2D (or by 8 in 3D). The number of applications determines the width of the Gaussian.

The Difference of Gaussian (DOG) is achieved by subtracting the binomial kernel from itself at a distance along one of the cardinal axes proportional to the number of applications. The size of the underlying Gaussian convolution kernel, and the proportional distance at which the results are subtracted, determine the scale of the resulting partial derivative approximation. A gradient in  $m$  dimensions is achieved by applying a series of  $m$  DOG kernels, one along each cardinal axis.



**Fig. A.2** Difference of Gaussian (DOG) for binomial kernels (dark outline in Fig A.1).

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