CS354

Nathan Sprague

November 5, 2020

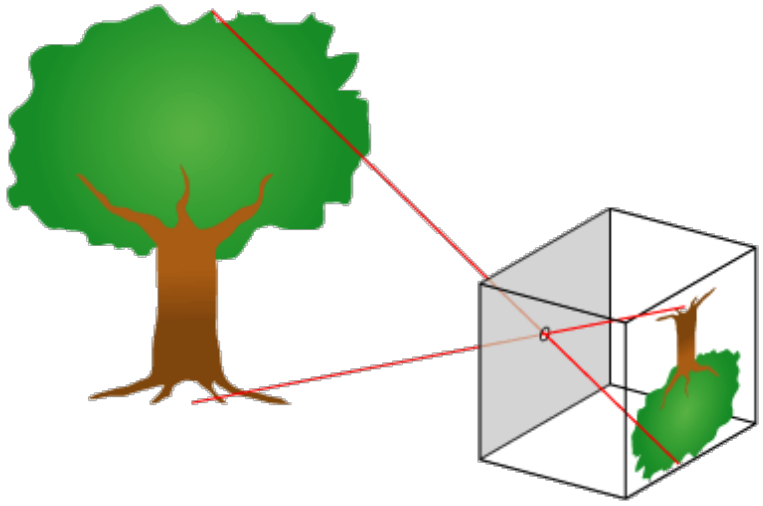
Computer Vision and Image Processing

- Computer Vision:
  - Working backward from an image of a scene to a description of the scene. The description could include:
    - 3D structure
    - Object labels
    - Complex descriptions: "The boy is sneaking up on his mother"
  - All of these are hard.

Computer Vision and Image Processing

- Computer Vision:
  - Working backward from an image of a scene to a description of the scene. The description could include:
    - 3D structure
    - Object labels
    - Complex descriptions: "The boy is sneaking up on his mother"
  - All of these are hard.
- Image processing:
  - Low level image transformations
    - blurring, sharpening, resizing etc.
  - Computer vision generally involves some initial image processing.

Image Formation



http://commons.wikimedia.org/wiki/File:Pinhole-camera.png

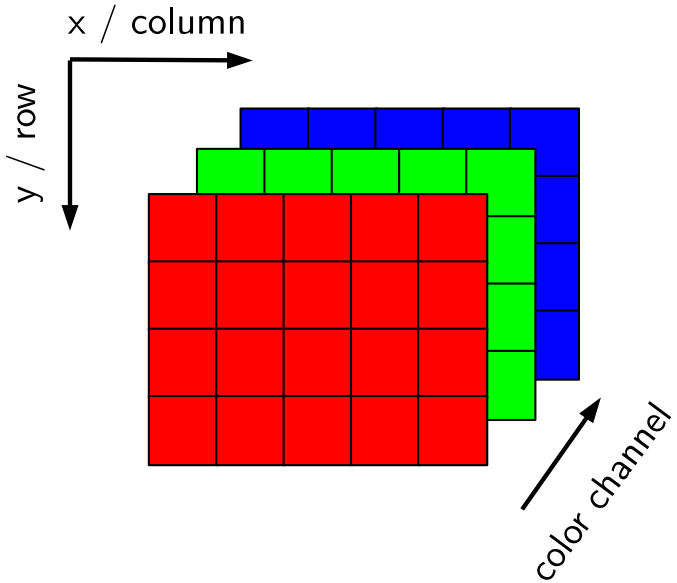
$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \sim \begin{bmatrix} f_x & 0 & 0 & 0 \\ 0 & f_y & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

https://staff.fnwi.uva.nl/r.vandenboomgaard/IPCV20162017/LectureNotes/CV/PinholeCamera/PinholeCamera.html

OpenCV

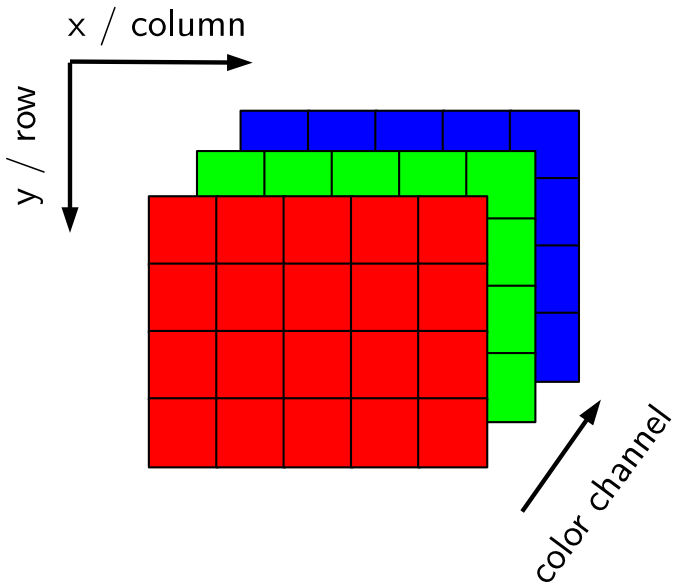
- OpenCV is an old and widely used computer vision library
- Default computer vision library used with ROS
- Written mostly in C++, with Python bindings
- Python OpenCV uses numpy arrays to represent images

Image Representations



- Color images are often stored as a collection of RGB triples
- (0, 0, 0) is black, (255, 255, 255) is white.
- RGB Color Model

Images In Numpy



- We will work with images stored as three-dimensional numpy arrays:
  - `img[row, col, color]`
- `img[0, 0, 0]` - Upper-left red value
- `img[3, 4, 2]` - Lower-right blue value
- `img[0:1, 0:2, :]` - Crop of upper left corner

Arithmetic with Images

- Many low level operations on image can be performed either with OpenCV *or* with numpy:
- OpenCV Arithmetic Tutorial
- By default, images are 8-bit unsigned integers (which can lead to unexpected results.)

Why is Computer Vision Hard?

- Let's look at some balloons...

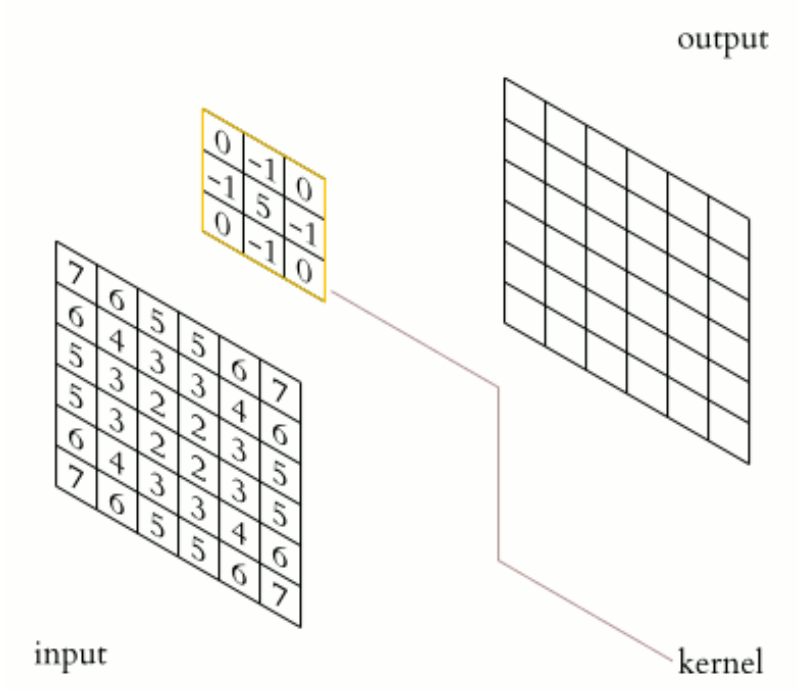
Why is Computer Vision Hard?

- Let's look at some balloons...
- Computer vision is hard (in part) because there is no simple mapping from an object to its pixel-level appearance
- Appearance is influenced by
  - Lighting
  - Viewing angle and distance
  - Camera properties

Image Processing - Convolutions

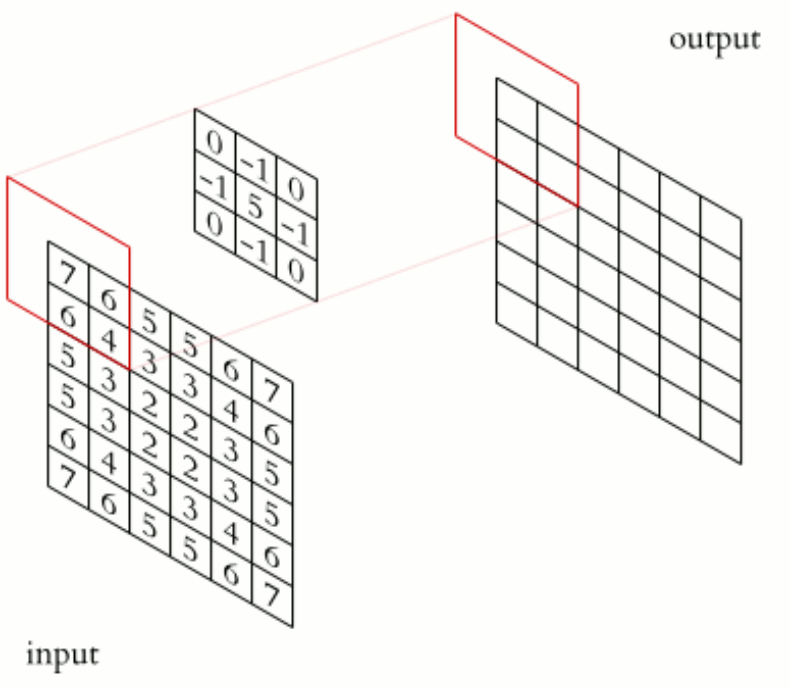
- Many low-level image processing tasks can be handled with the convolution operator:
  - Image Convolutions

Image Processing - Convolution Example



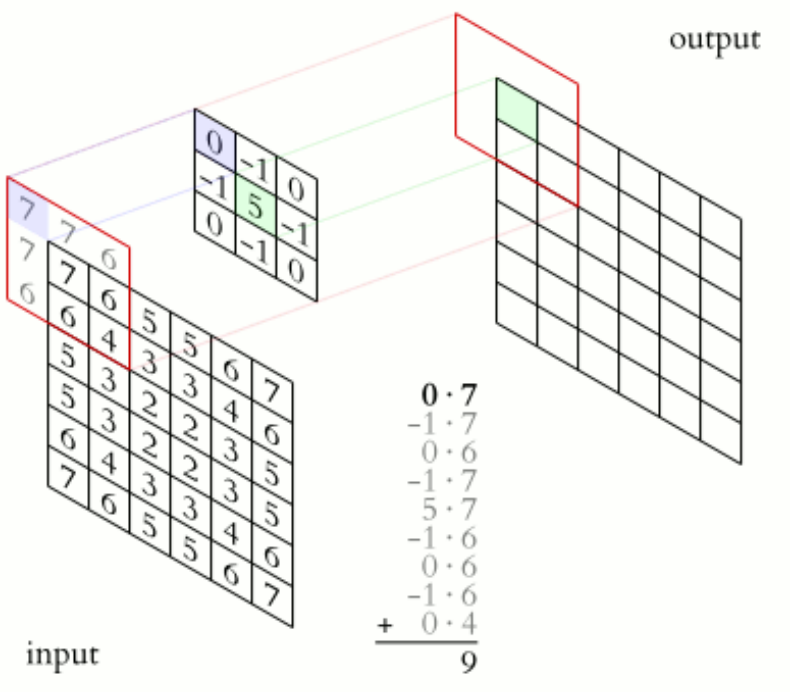
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



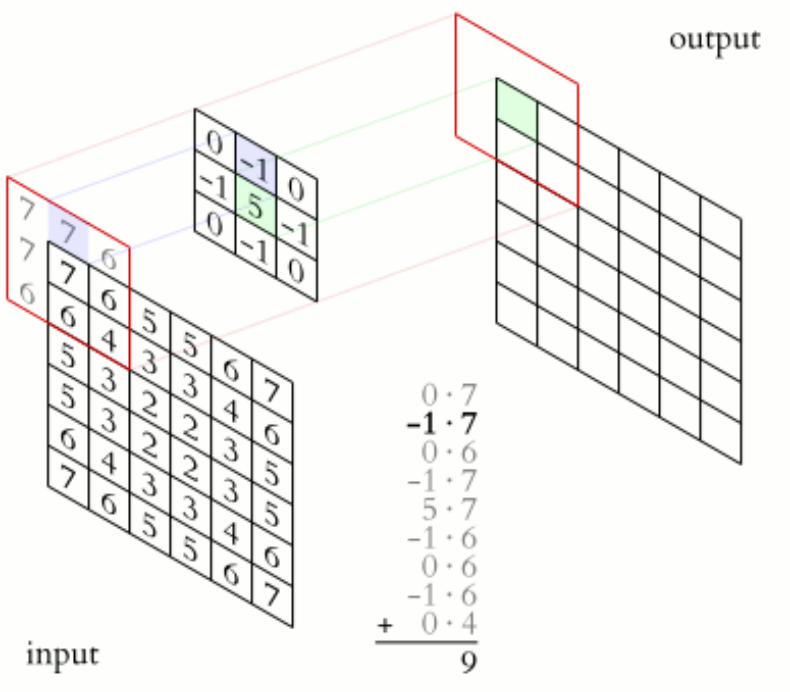
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



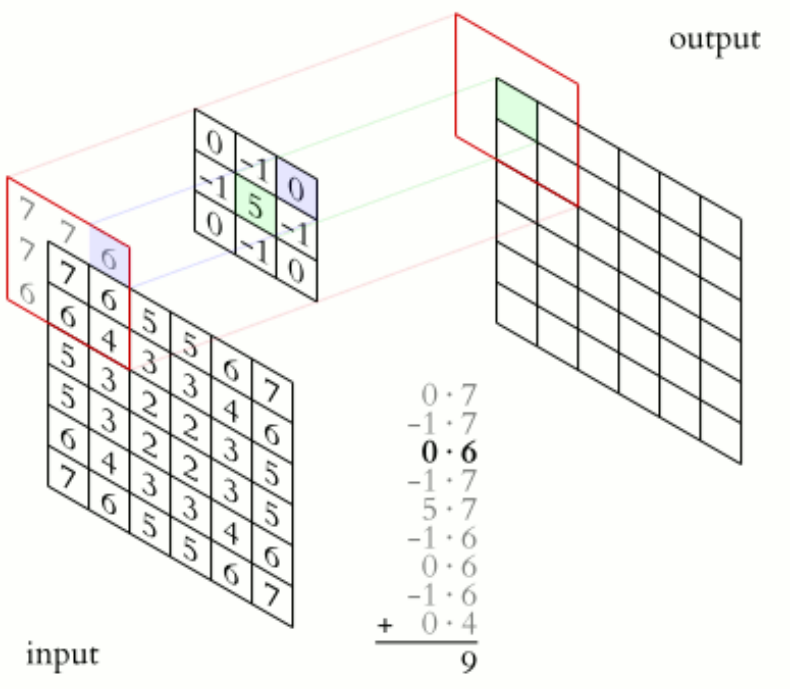
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



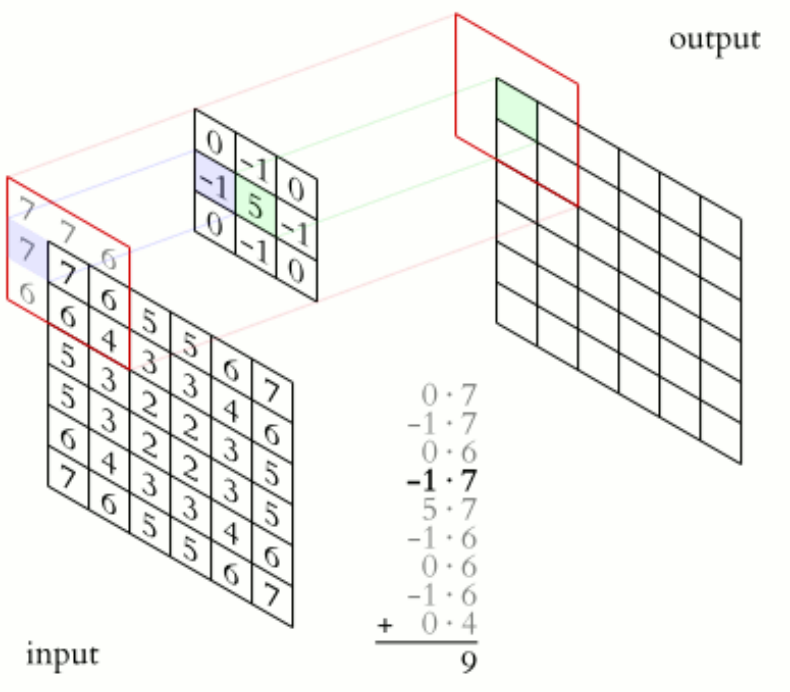
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



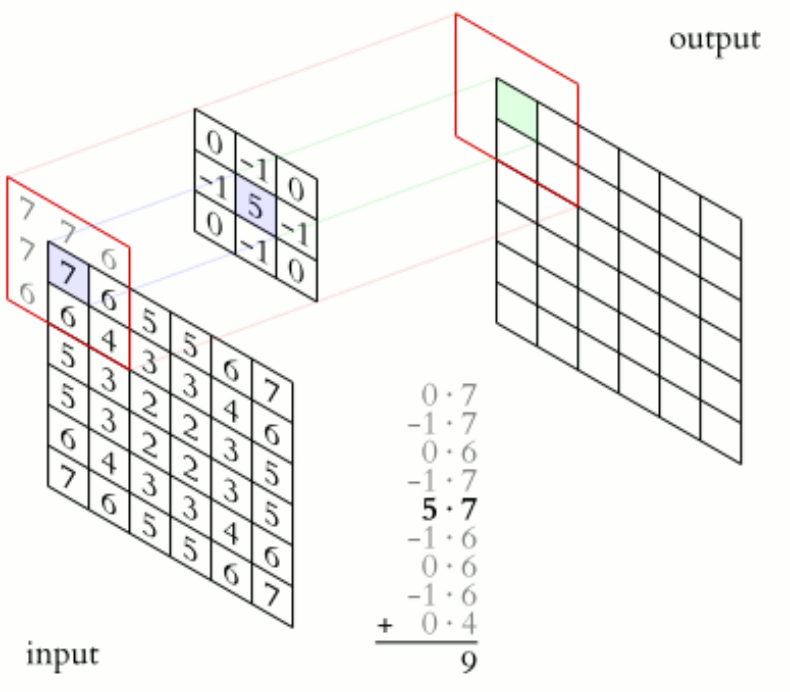
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



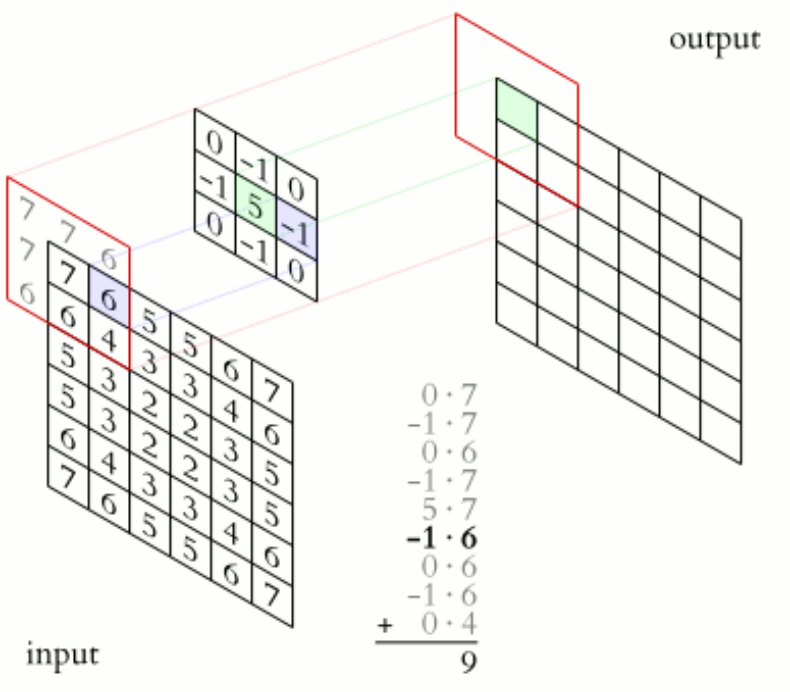
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



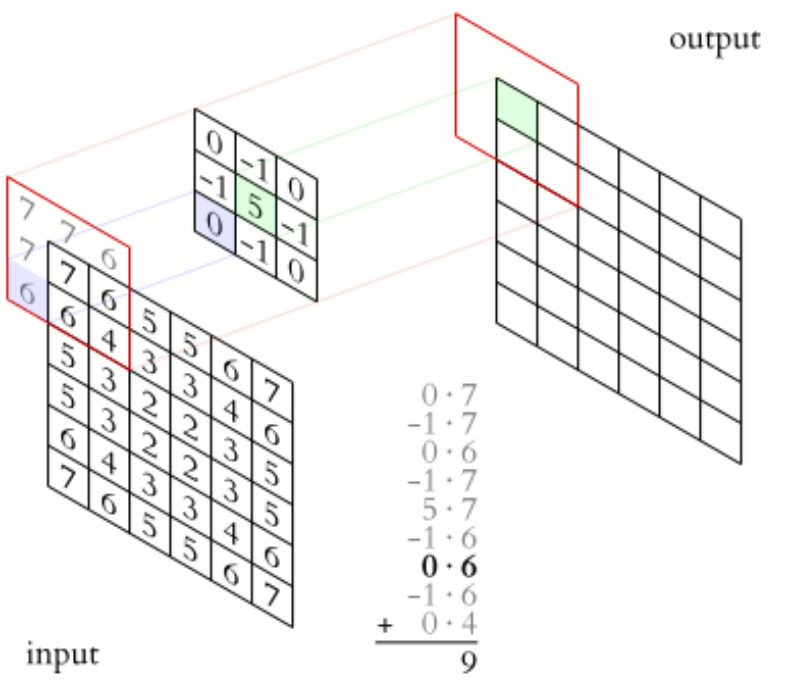
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



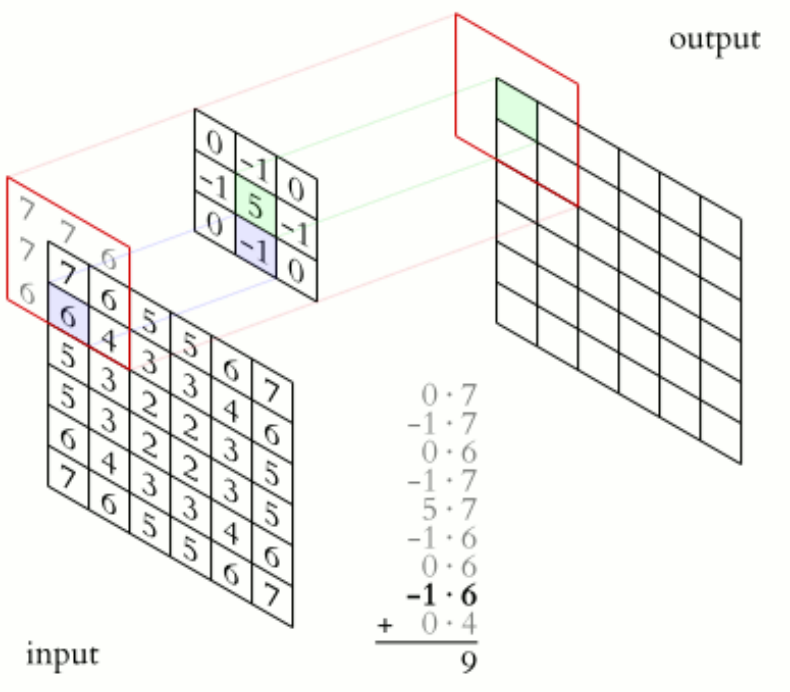
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



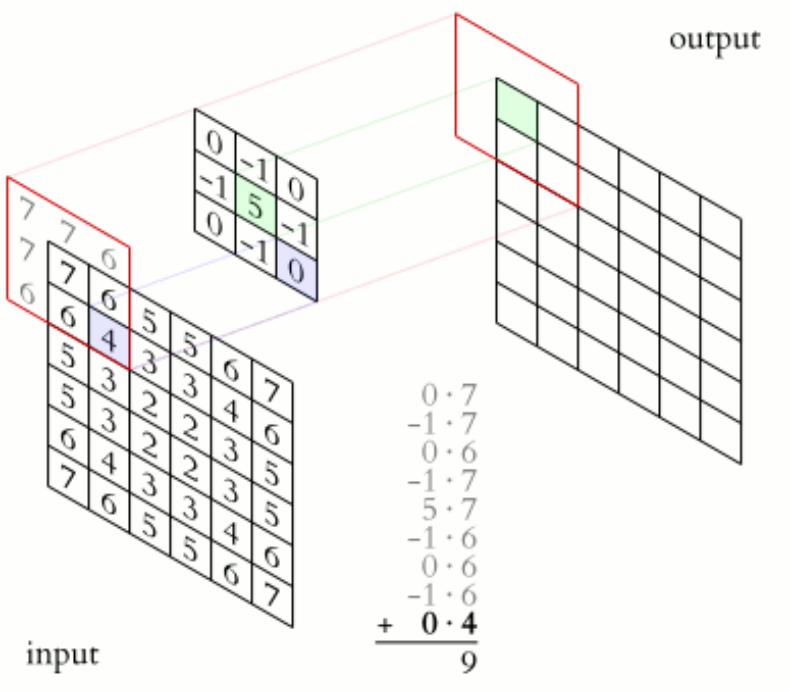
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



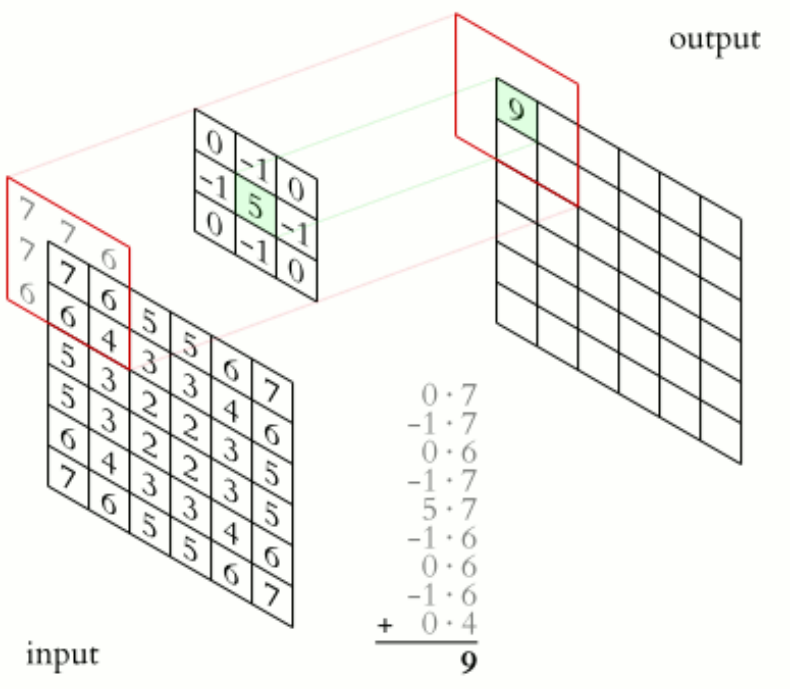
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



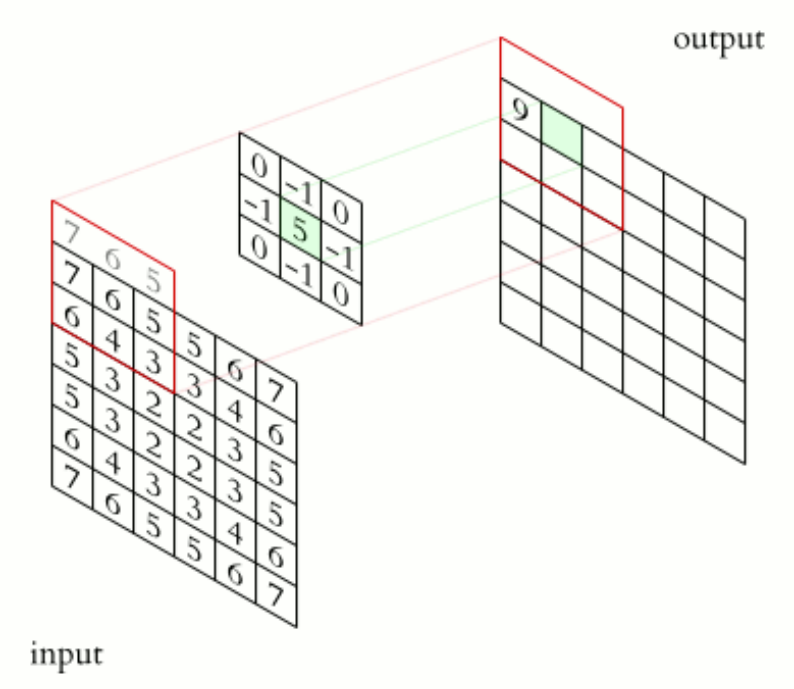
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



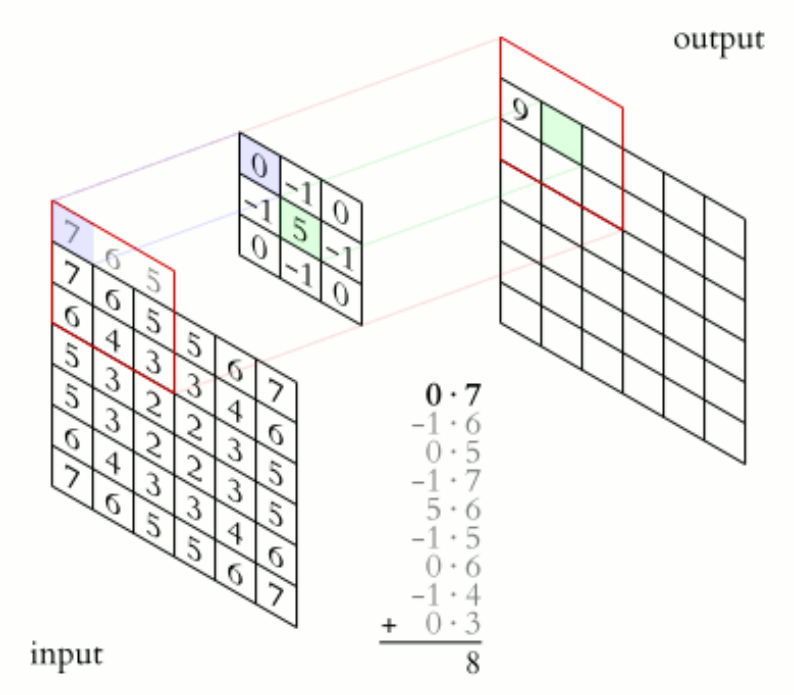
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



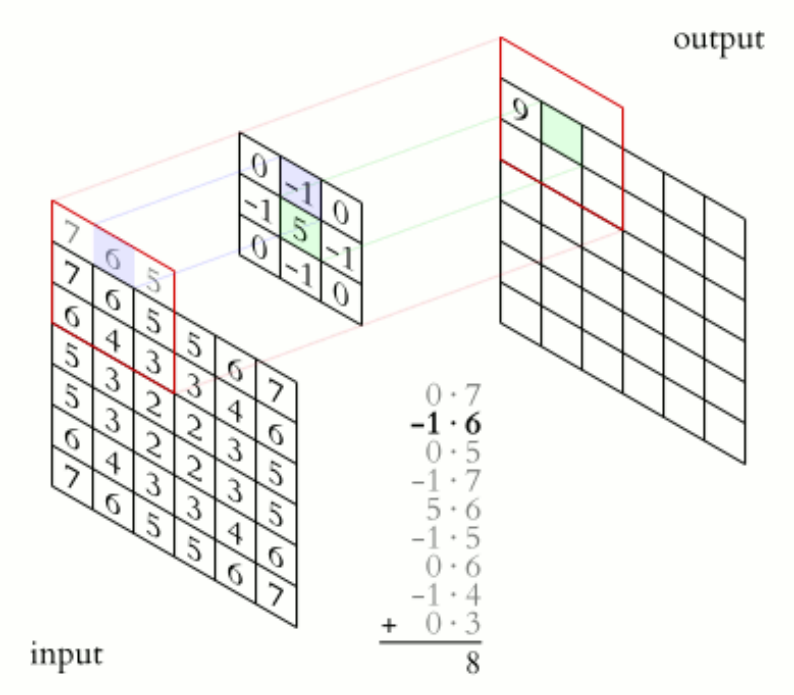
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



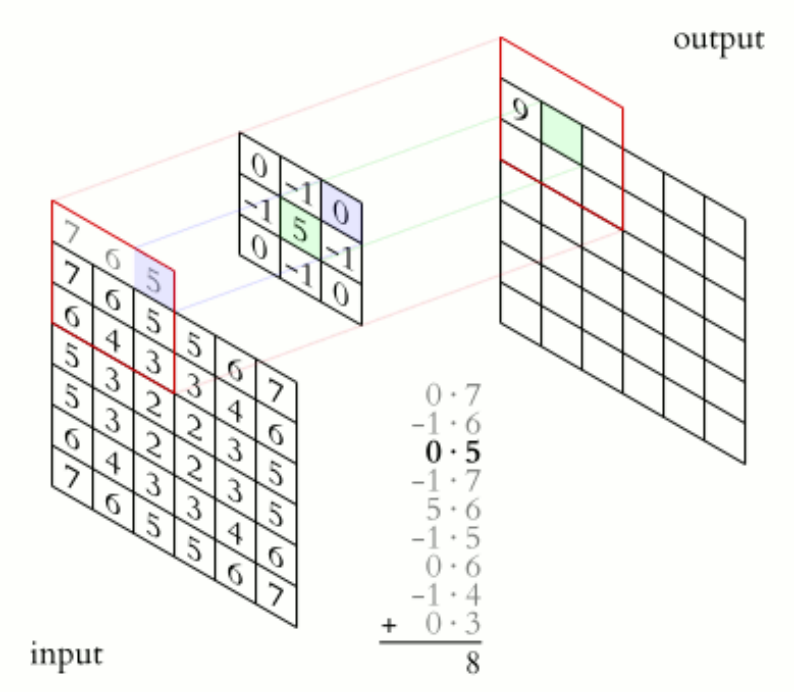
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



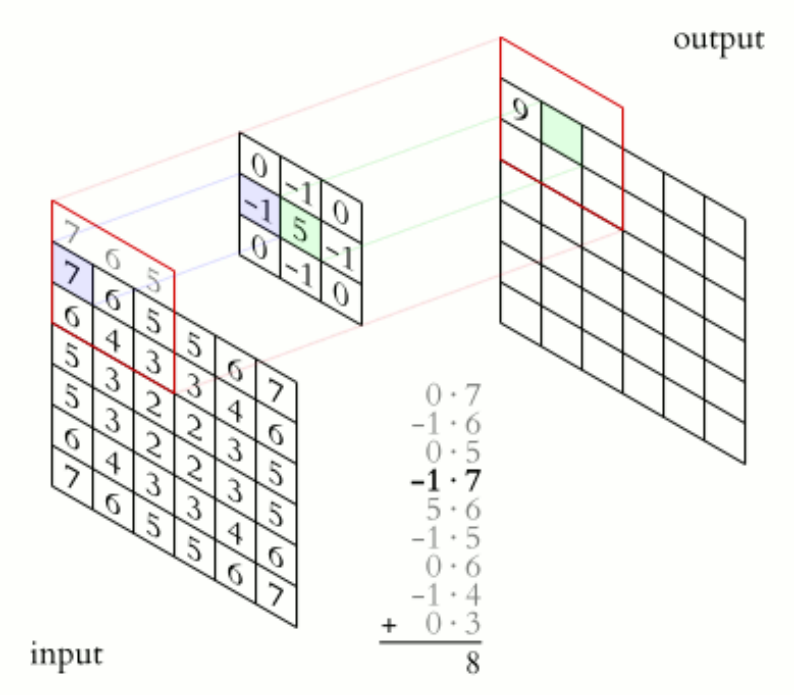
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



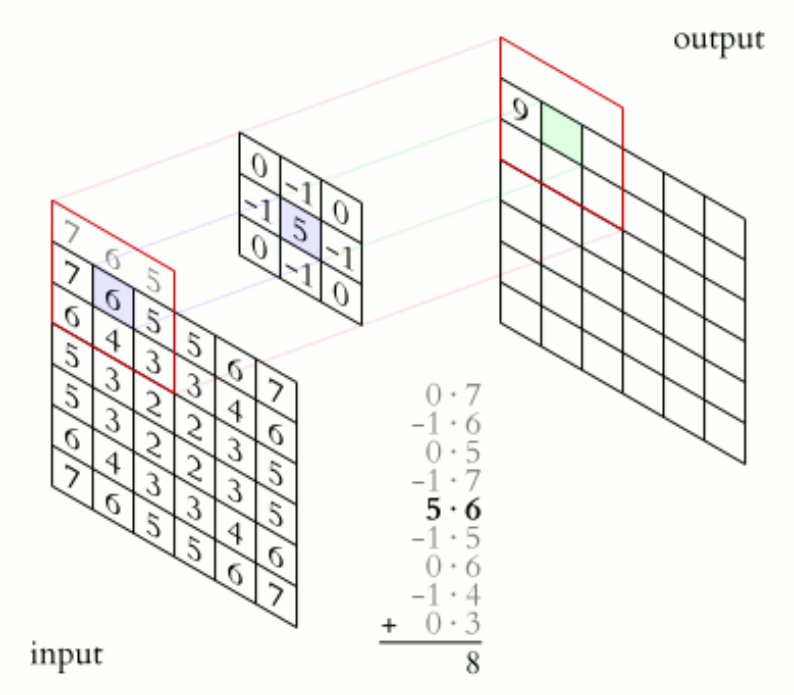
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



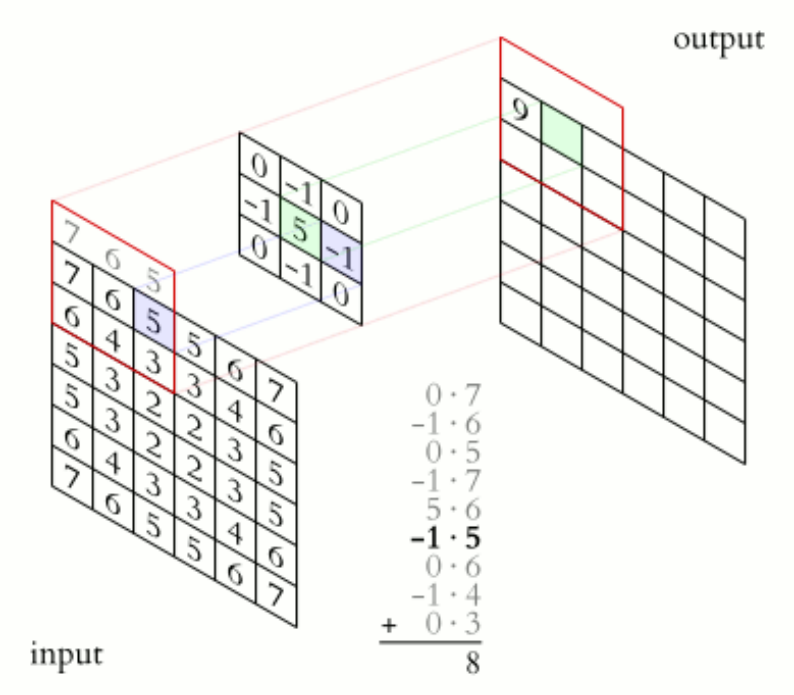
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



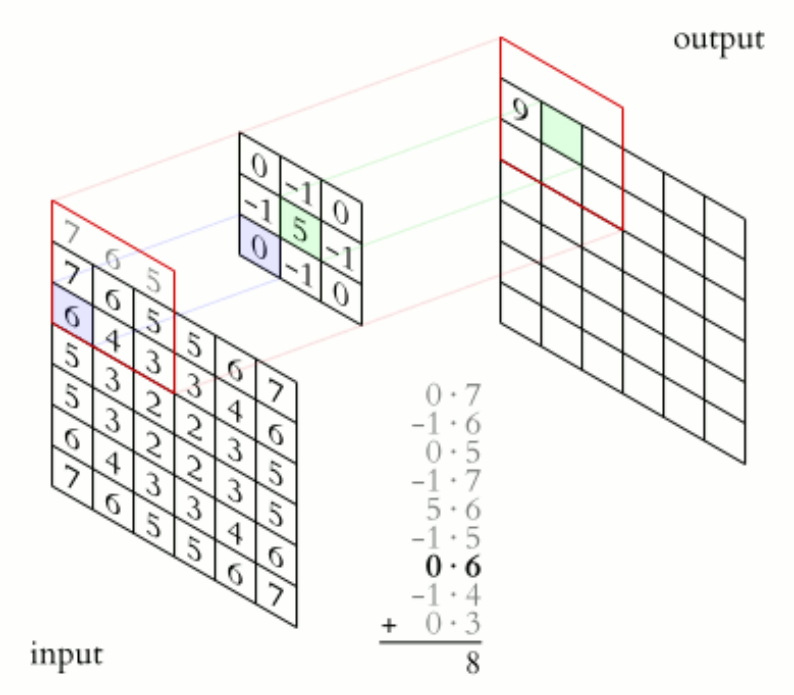
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



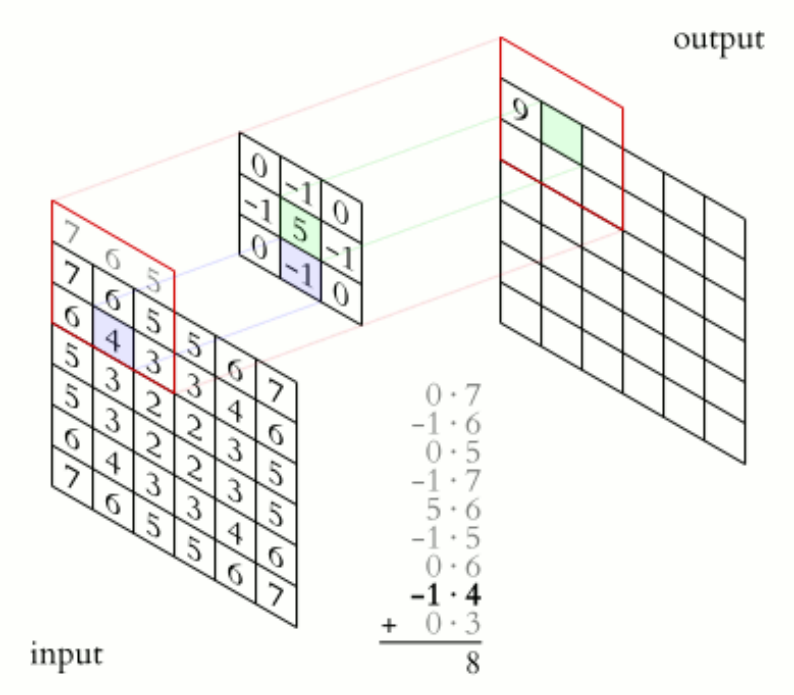
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



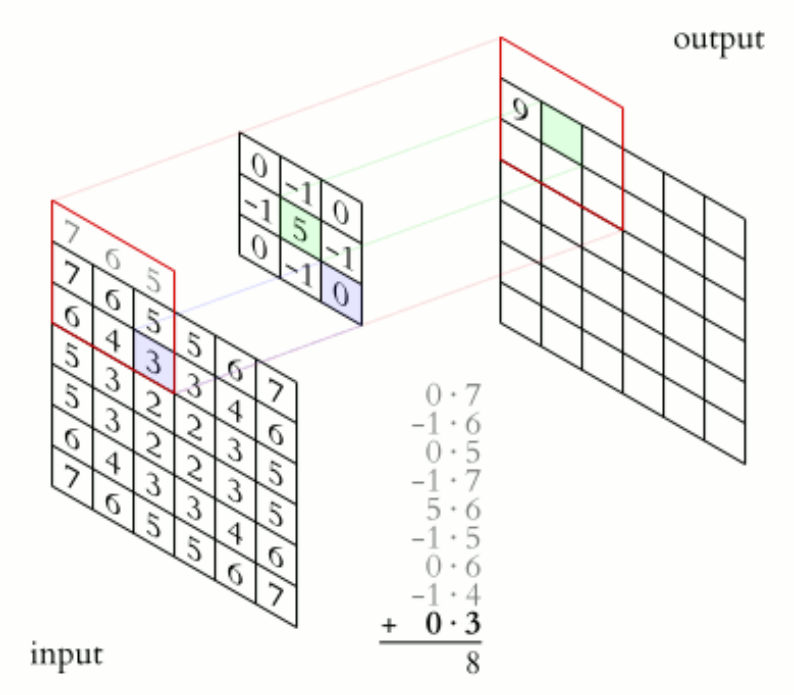
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



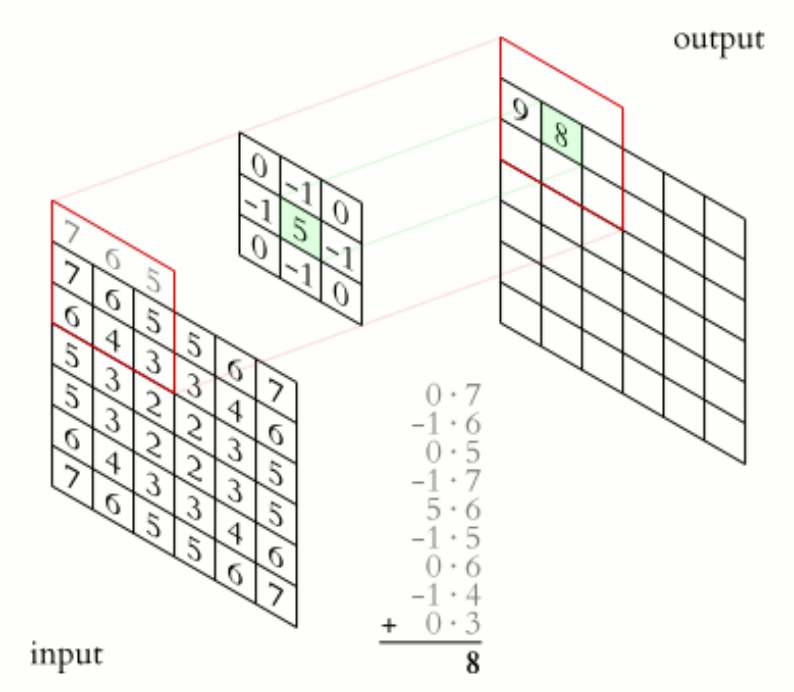
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



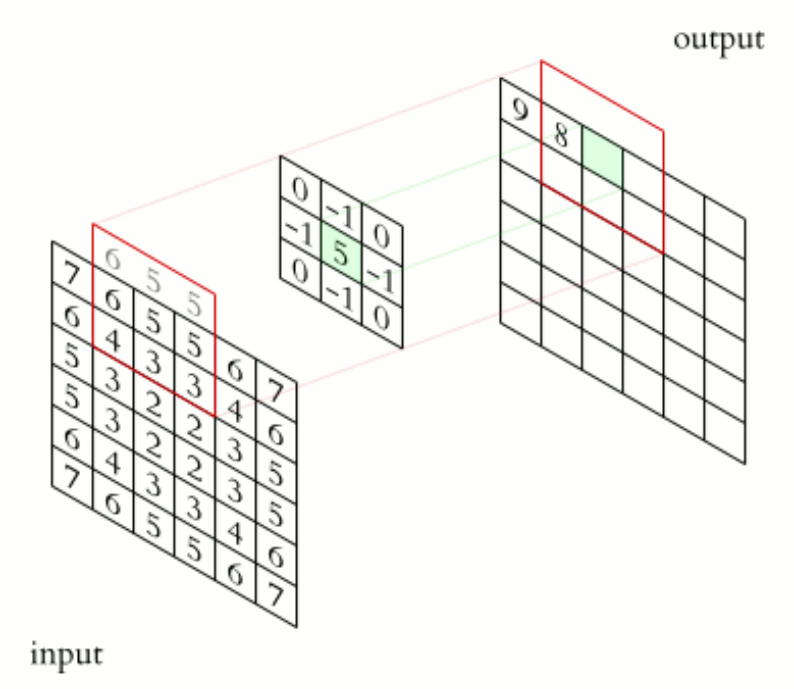
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



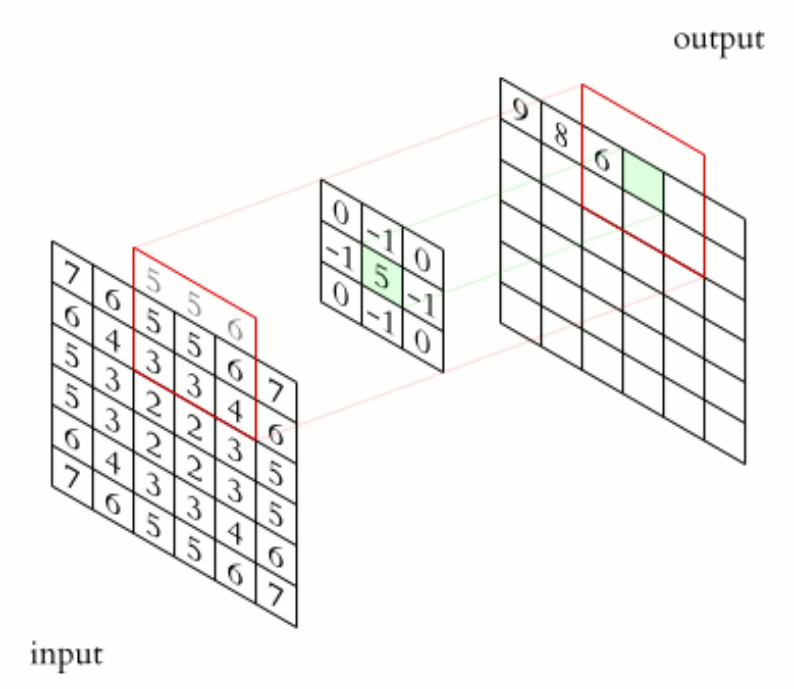
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



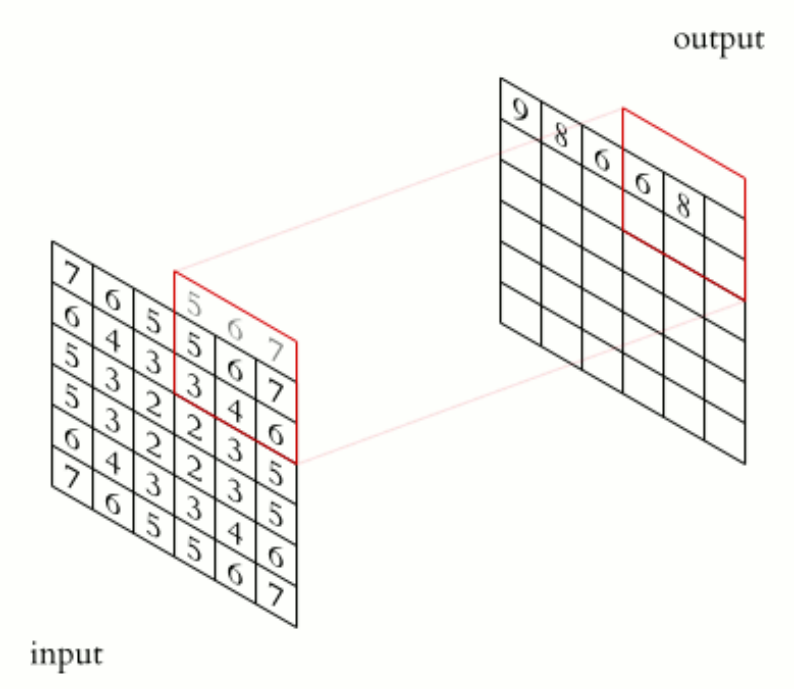
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



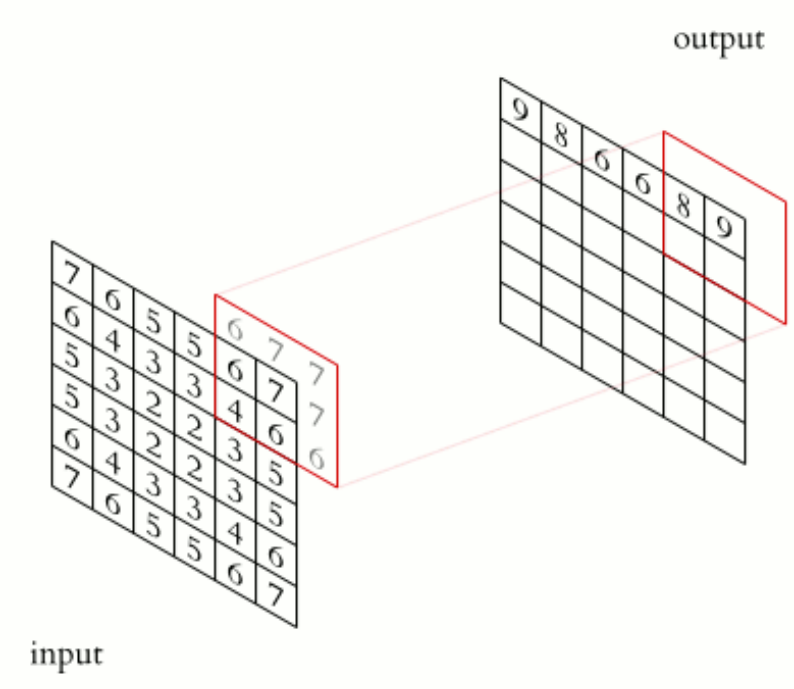
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



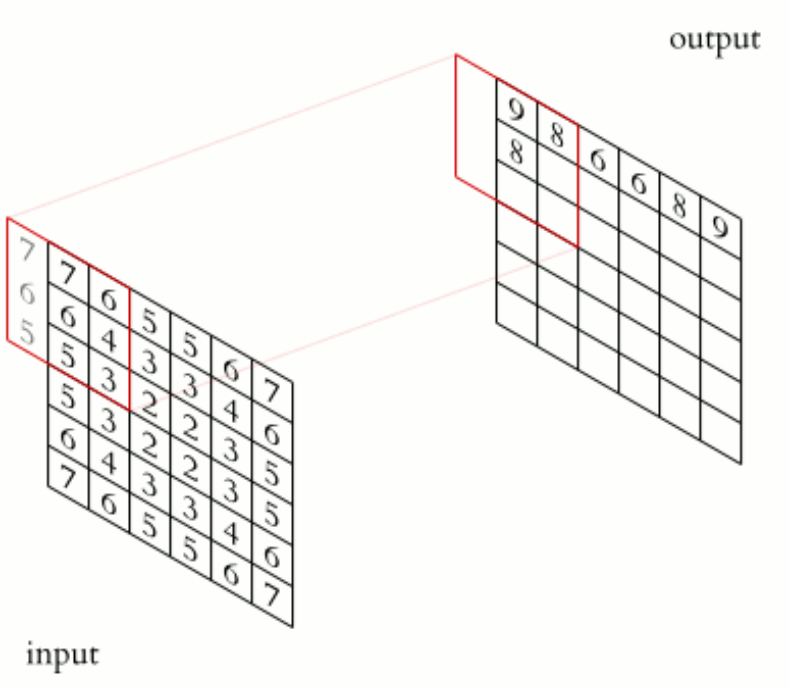
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



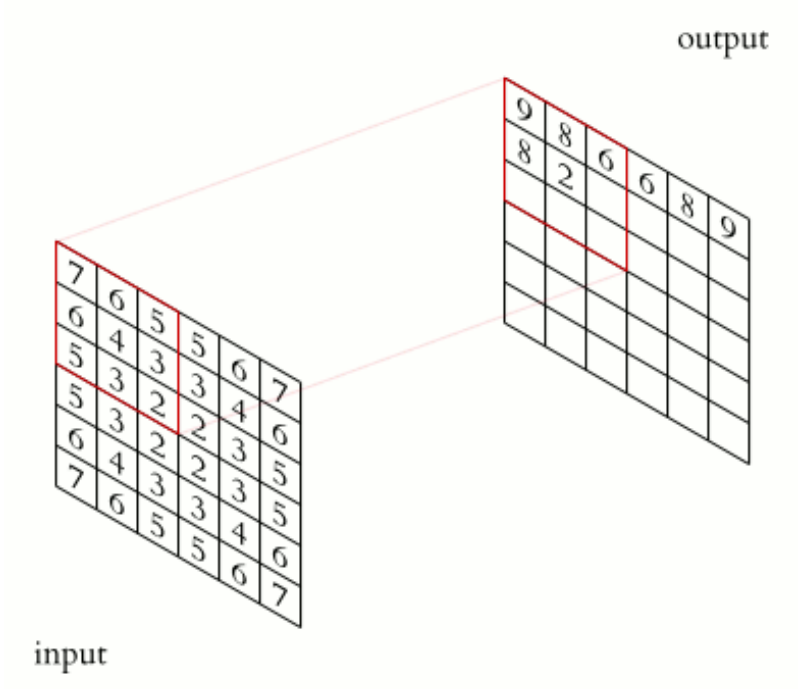
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



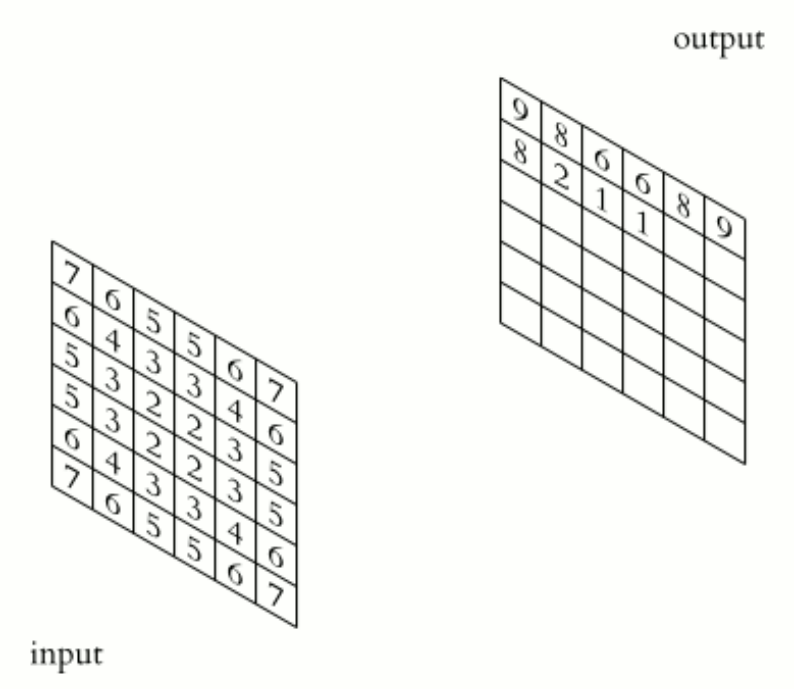
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



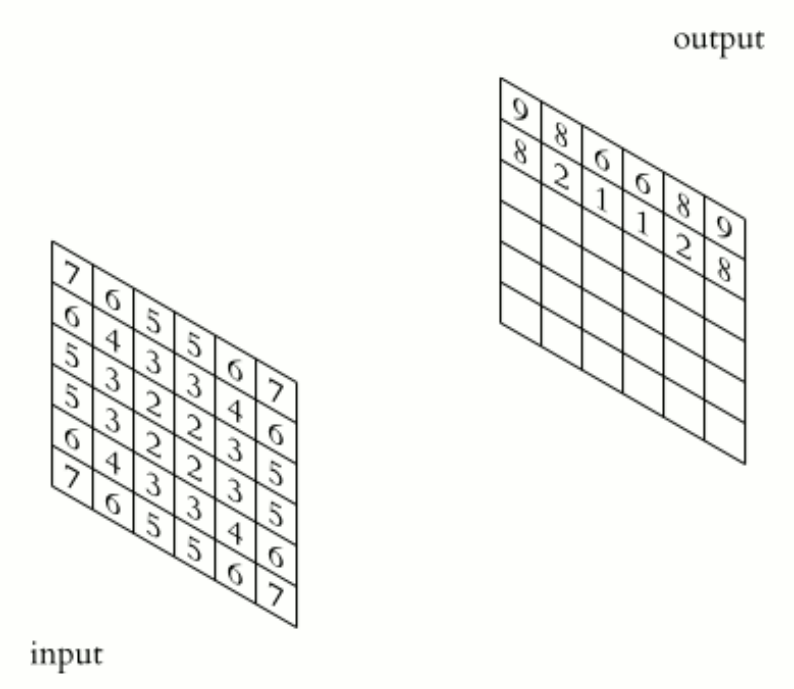
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



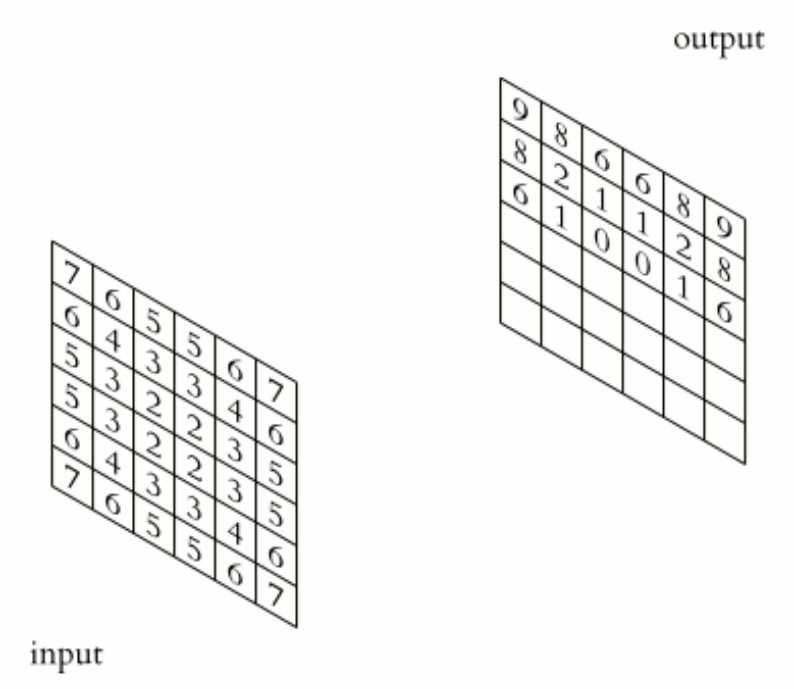
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



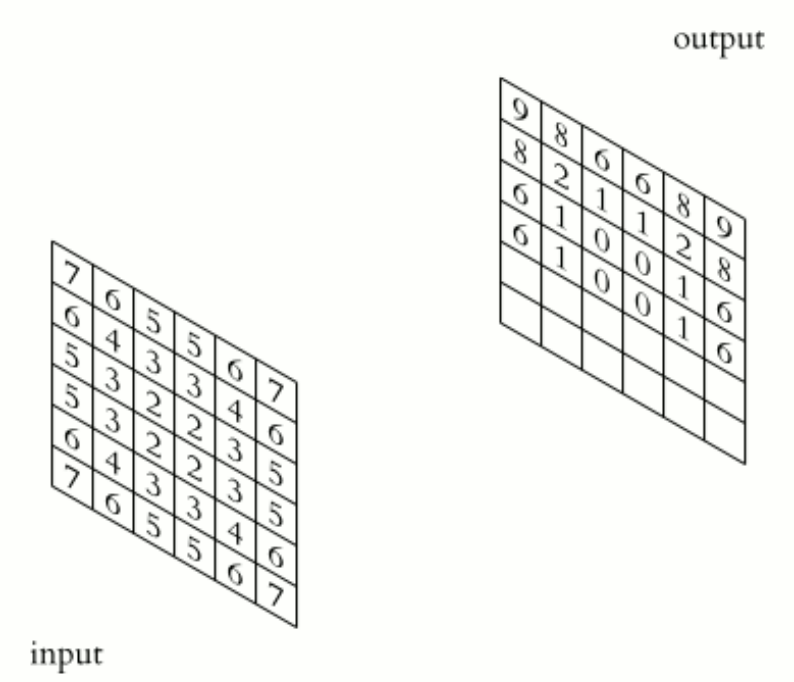
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



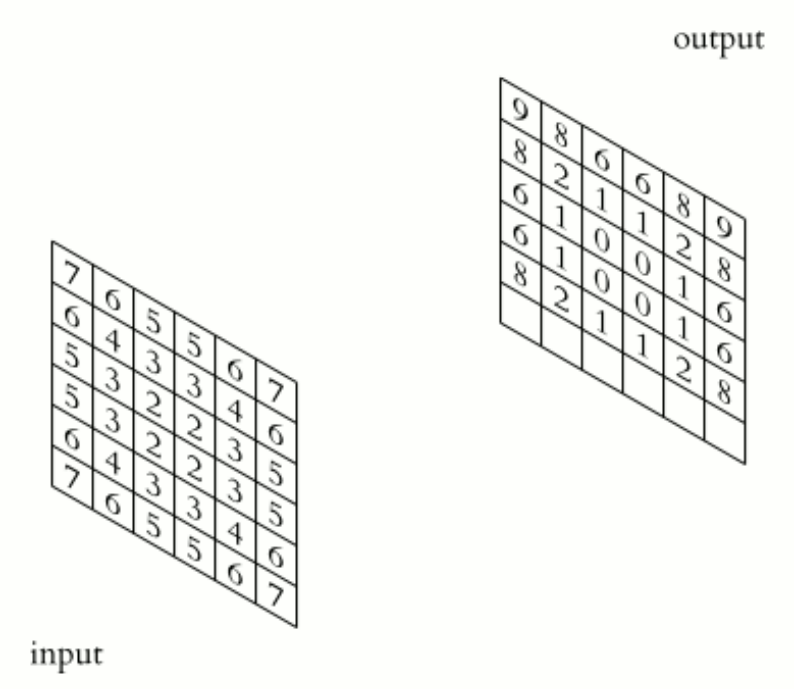
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



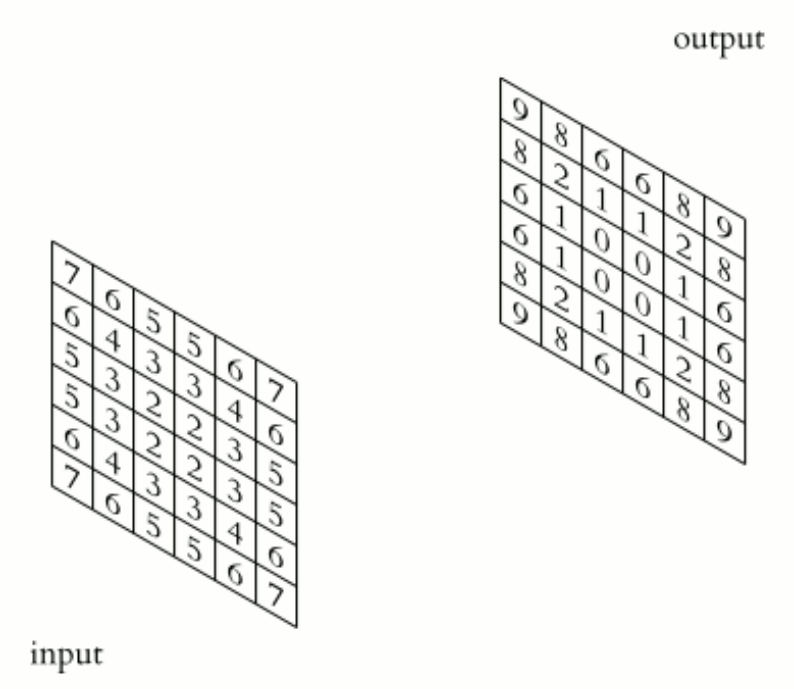
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



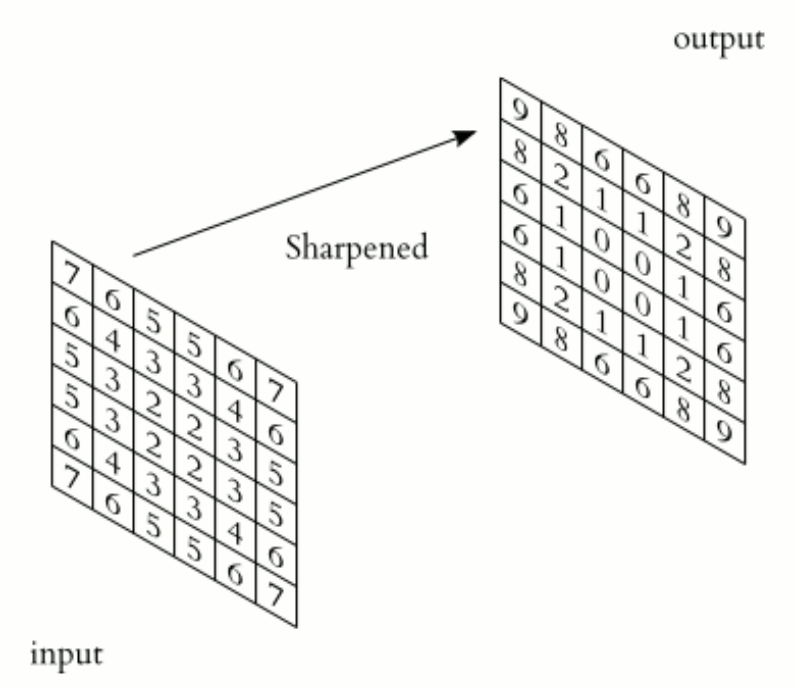
http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif
By Michael Plotke [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)]

Image Processing - Convolution Example



http://upload.wikimedia.org/wikipedia/commons/4/4f/3D_Convolution_Animation.gif