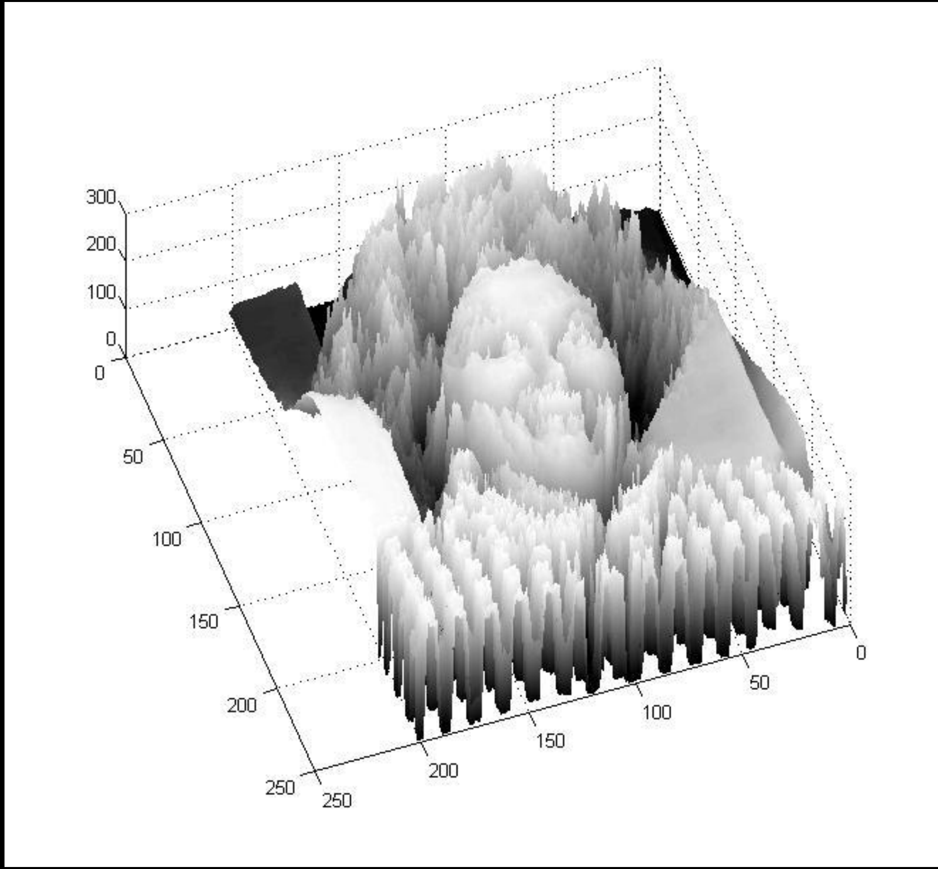
CS4495/6495
Introduction to Computer Vision

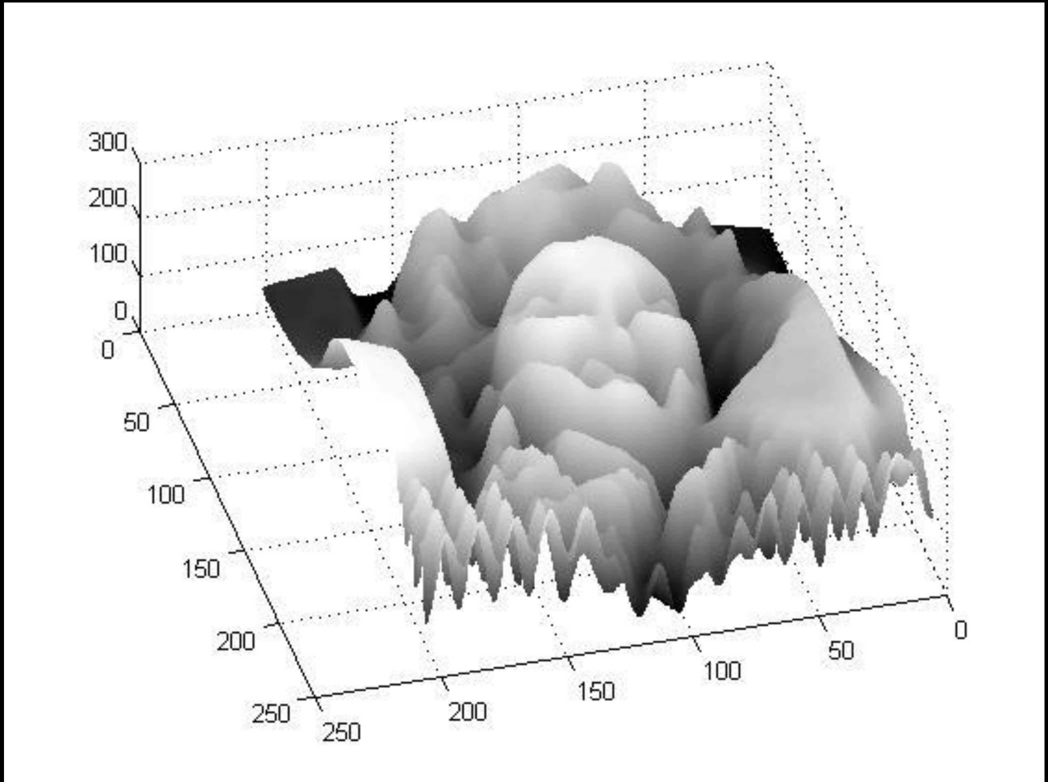
2A-L1 *Images as functions*

Images as functions

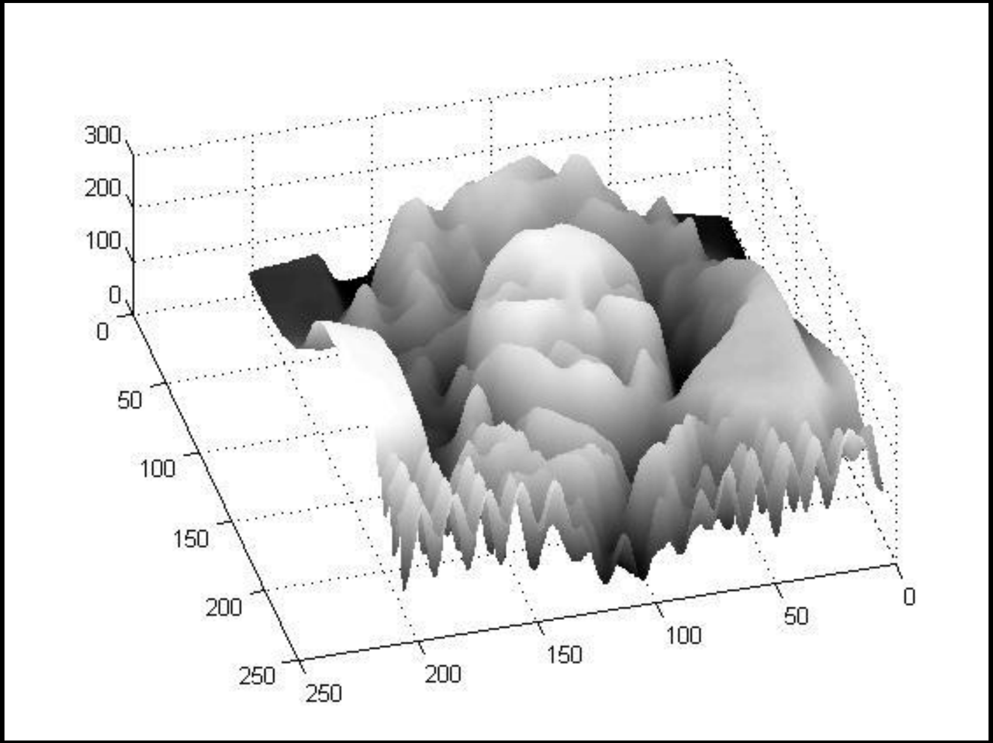
Images as functions



Images as functions



Images as functions



Quiz

An image can be thought of as:

a) A 2-dimensional array of numbers ranging from some minimum to some maximum
b) A function I of x and y: $I(x, y)$
c) Something generated by a camera.
d) All of the above.

Images as functions

We think of an image as a *function*, f or I, from R^2 to R:

- $f(x, y)$ gives the intensity or value at position (x, y)

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Practically define the image over a rectangle, with a finite range:

$$f\colon [a, b]\ x\ [c, d] \rightarrow [min, max]$$

Color images as functions

A color image is just three functions “stacked” together. We can write this as a “vector-valued” function:

$$f(x,y) = \begin{bmatrix} r(x,y) \\ g(x,y) \\ b(x,y) \end{bmatrix}$$

The real Phyllis

```
>> pd(40:60,30:40)

ans =

   152   122    99    83   122   120   154   150   123   141   112
   102   140   109   114   125   124    69   134   123   141   132
   138   160   135   109   104    89    91   145   128   102   154
   101   147   165    87    93    97   110   145   157   124   141
    58    68    96   115    80    98   137   160   145   168   166
    57   127    62    92   145   127    93   121   168   221   157
    69   108    74    71   156   119   106   140   156   161   158
   116   132   101    60   134   159   110   125   153   145   123
   109   119   130   113    80   176   121   108   111   152   133
   135    77   102   134   127   136   154   130   139   120   160
   175   127   112   145   153   125   160   126   103    94   166
   205   187   151    87   128   154   124   174    96   129   142
   206   211   207   171   153   146   173   194   125   129   164
   214   205   235   200   170   162   151   151   183   152   107
   225   199   211   203   125   145   154   181   201   184   137
   207   203   172   169   170   127   116    95   197   187   138
   171   208   150   157   184   153   109   119   148   182   138
   111   170   150   116   128   170   144   132   119   176   132
   101   172   168   130   112   131   116   136   129   137   121
   103   167   164   131   104   106    96   111   106   103   139
    92   136   146   138    92    63    73   101   120   126   134
```

Digital images

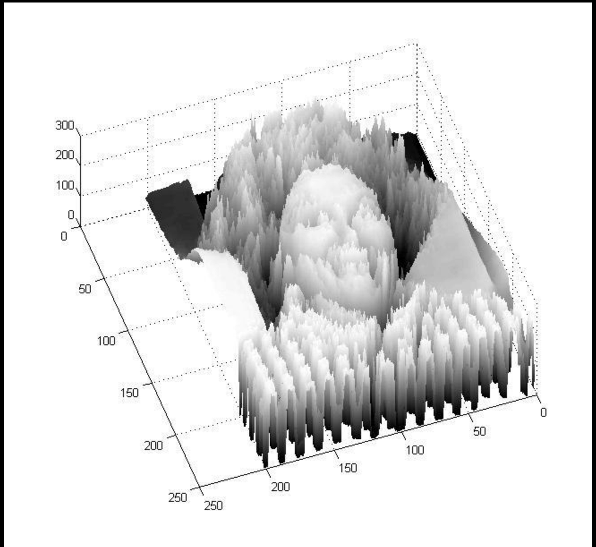
In computer vision we typically operate on digital (discrete) images:

Sample the 2D space on a regular grid

Quantize each sample (round to “nearest integer”)

Digital images

Image thus represented as a *matrix* of integer values.

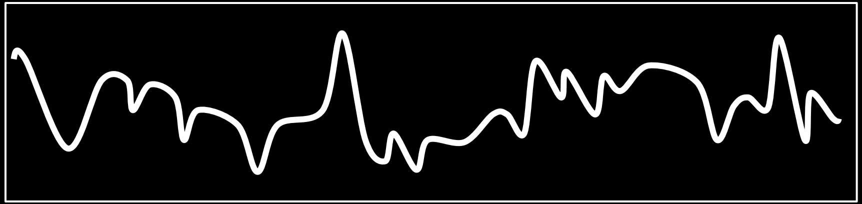


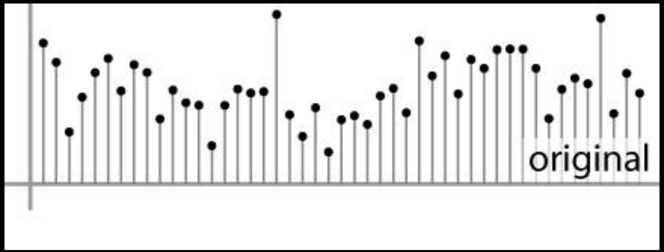
j

i

62	79	23	119	120	105	4	0
10	10	9	62	12	78	34	0
10	58	197	46	46	0	0	48
176	135	5	188	191	68	0	49
2	1	1	29	26	37	0	77
0	89	144	147	187	102	62	208
255	252	0	166	123	62	0	31
166	63	127	17	1	0	99	30

2D





1D

Matlab – images are matrices

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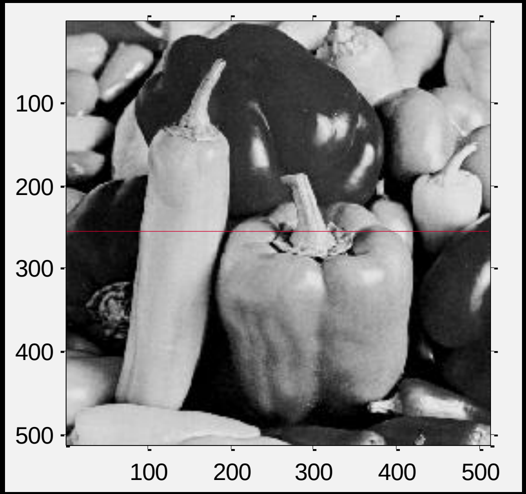
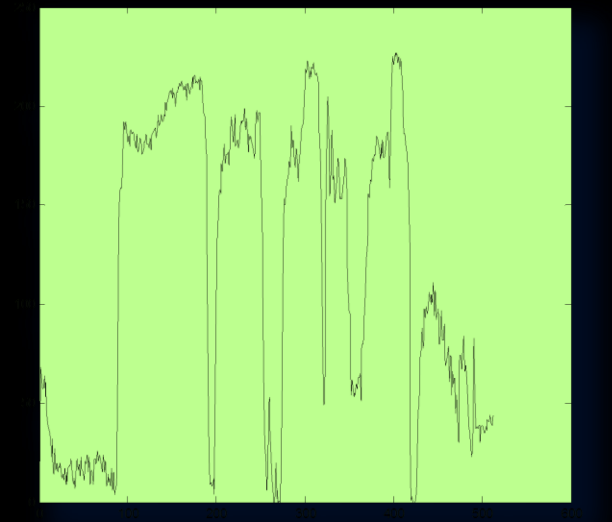
```
>> im = imread('peppers.png');  % semicolon or many numbers
>> imgreen = im(:,:,2);
```

Matlab – images are matrices

```
>> im = imread('peppers.png');  % semicolon or many numbers
>> imgreen = im(:,:,2);
>> imshow(imgreen)
>> line([1 512], [256 256],'color','r')
>> plot(imgreen(256,:));
```





Noise in images

- Noise is just another function that is combined with the original function to get a new – guess what – function

$$\vec{I}'(x,y) = \vec{I}(x,y) + \vec{\eta}(x,y)$$

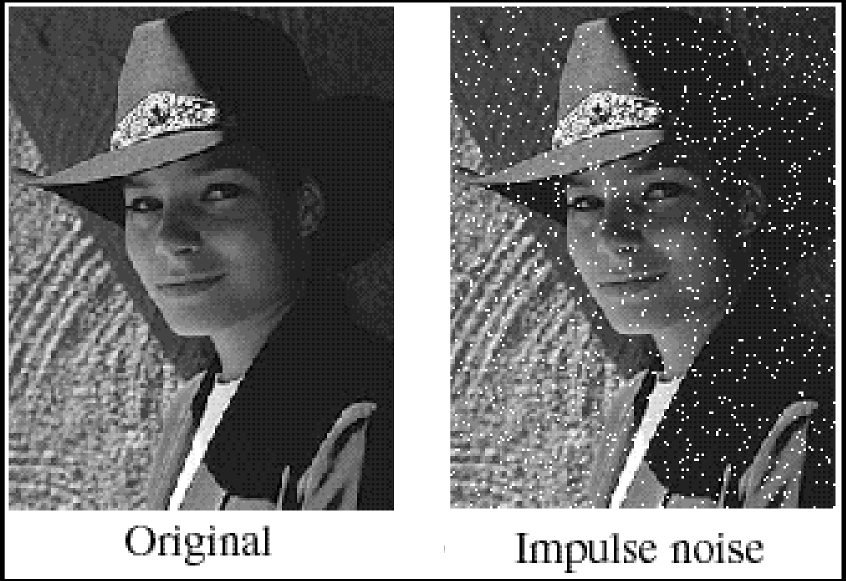
Common Types of Noise

Salt and pepper noise: random occurrences of black and white pixels

Original Salt and pepper noise

Common Types of Noise

Impulse noise: random occurrences of white pixels



Common Types of Noise

Gaussian noise: variations in intensity drawn from a Gaussian normal distribution

Original

Gaussian noise

Gaussian noise

```
>> noise = randn(size(im)).*sigma;

>> output = im + noise;
```

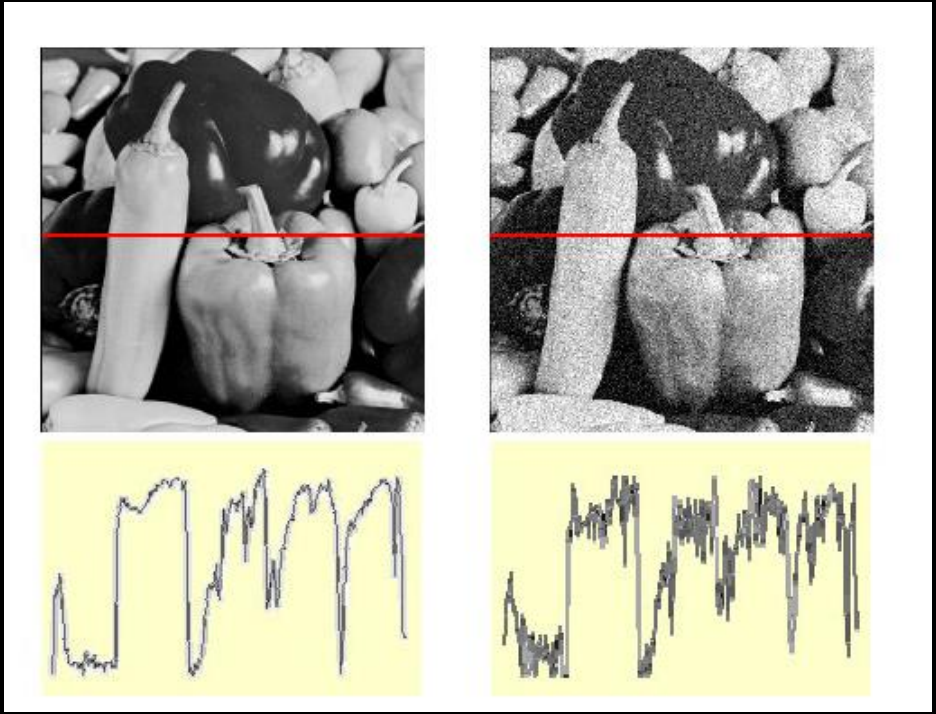


Fig: M. Hebert

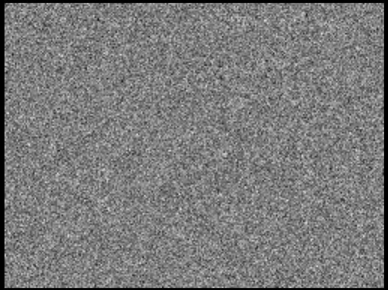
Quiz: Effect of σ on Gaussian noise

Noise images: Images showing noise values generated with different sigma

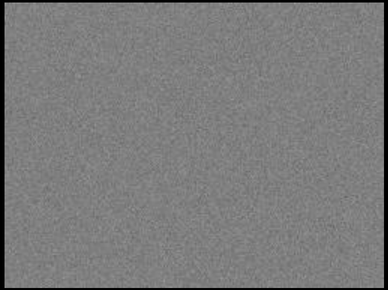
$$\sigma = 2, 8, 32, 64$$

Guess sigma for each noise image

```
noise = randn(size(im)).*sigma
```

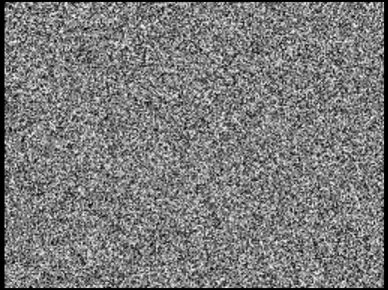


sigma =



sigma =

sigma =



sigma =

Quiz: Effect of σ on Gaussian noise

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Guess sigma for each noise image

```
noise = randn(size(im)).*sigma
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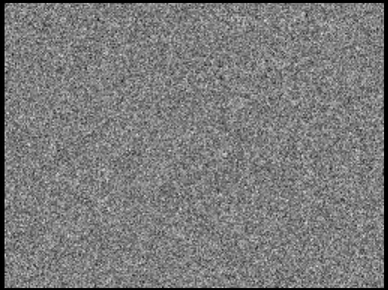
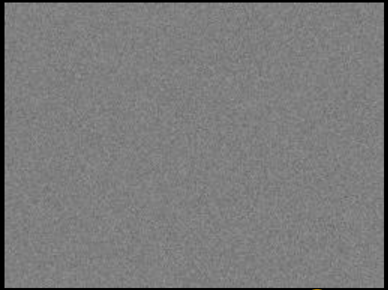
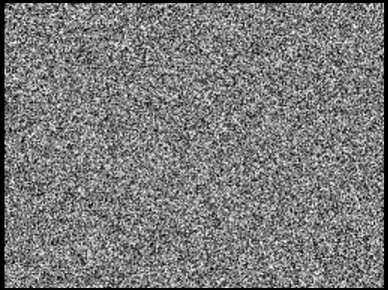


sigma = 32



sigma = 8

sigma = 2



sigma = 64

Values of σ to use

- A σ of 1.0 would be tiny if the range is [0 255] but huge if pixels went from [0.0 1.0].

- Matlab can do either and you need to be very careful - if in doubt convert to doubles.

Displaying images in Matlab

Look at the Matlab function imshow()

```
imshow(im,[LOW HIGH])
```

will display the image *im* with value LOW as black and HIGH as white.

Displaying images in Matlab

Look at the Matlab function imshow()

```
imshow(im,[])
```

will display the image *im* with the based on the range of pixel values in *im*.

Quiz

When adding noise to images as arithmetic operators we have to worry about:

a) The speed of the addition operation
b) The magnitude of noise compared to the range of the image
c) Whether we add the noise to the image or the image to the noise (the order of operation)
d) None of the above