Computer Vision – TP3
Digital Images

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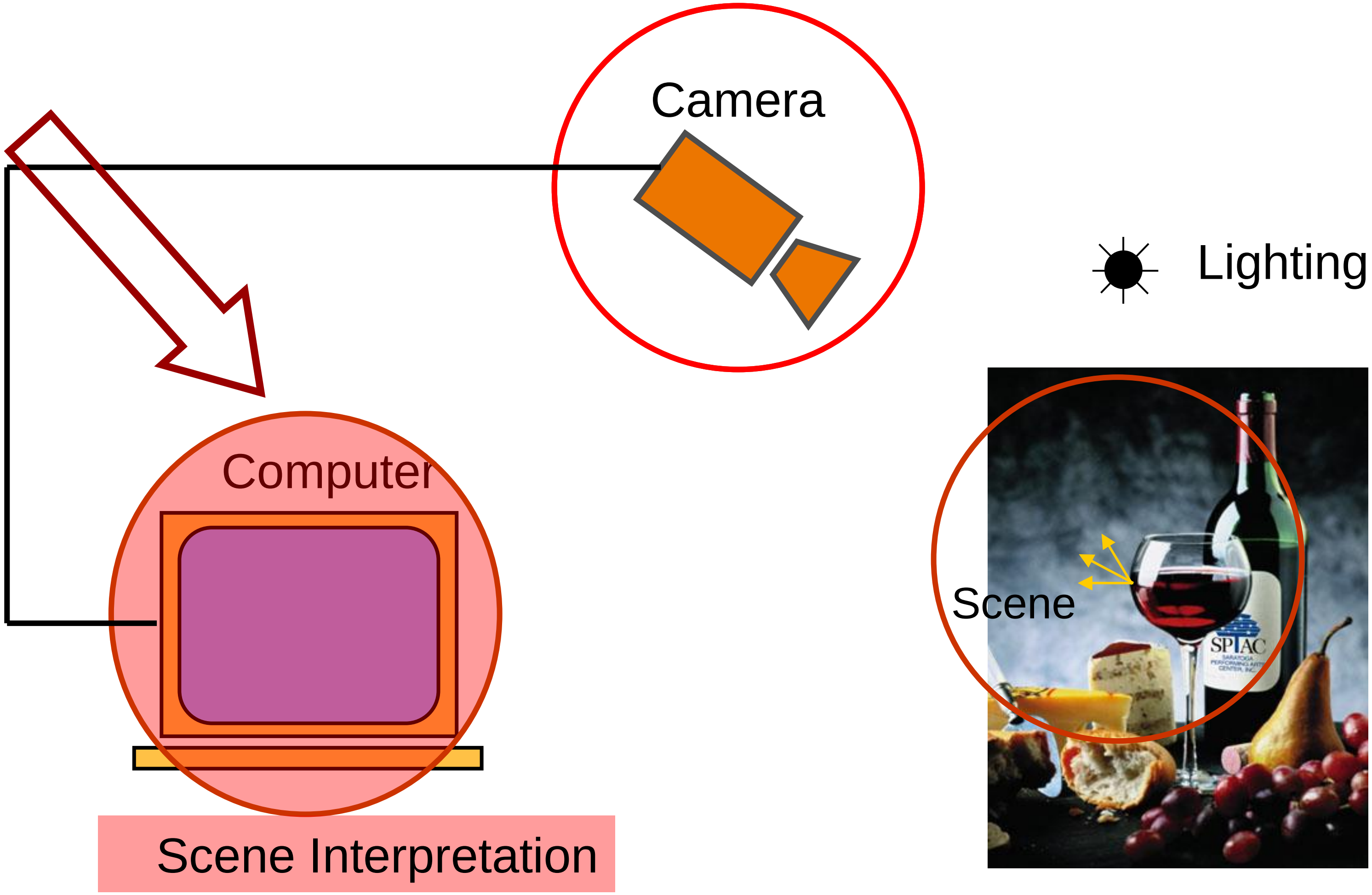
Outline

- Sampling and quantization
- Data structures for digital images

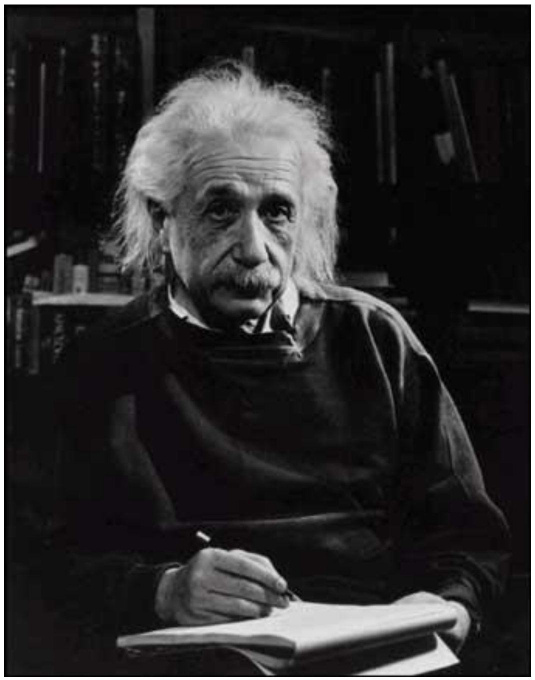
Topic: Sampling and quantization

- Sampling and quantization
- Data structures for digital images

Components of a Computer Vision System



Digital Images

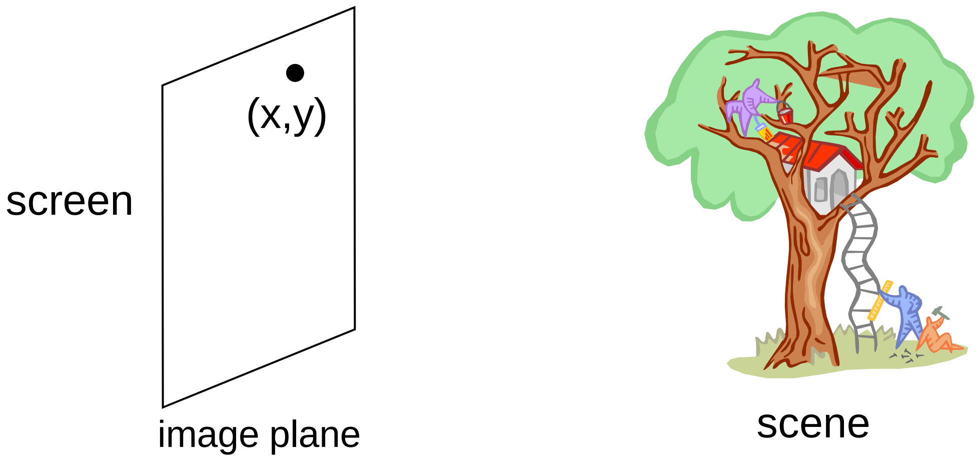


What we see

0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

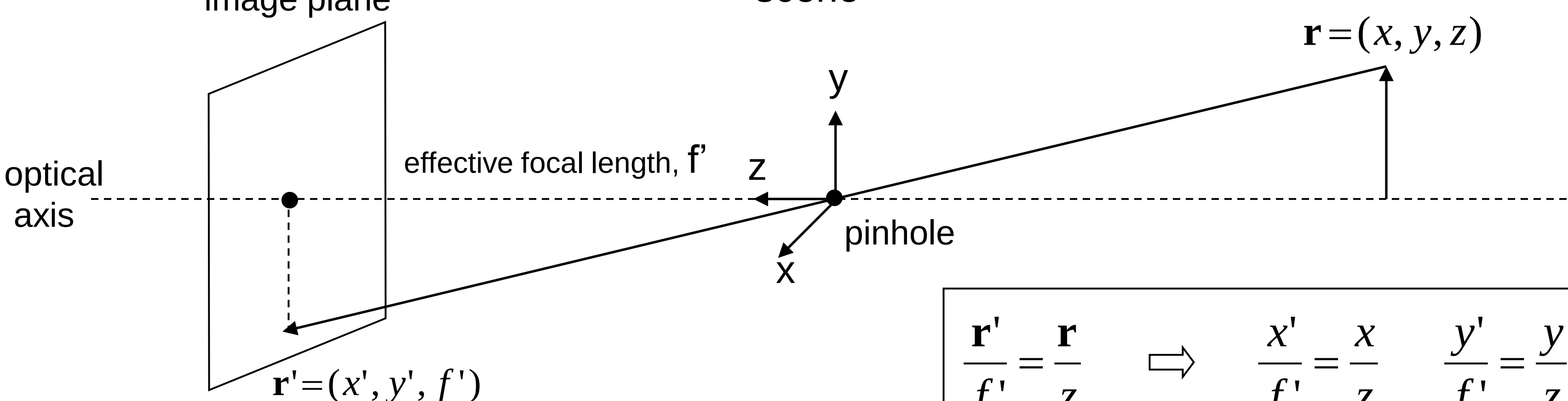
What a computer sees

Pinhole and the Perspective Projection



Is an image being formed on the screen?

YES! But, not a “clear” one.



$$\frac{\mathbf{r}'}{f'} = \frac{\mathbf{r}}{z} \quad \Rightarrow \quad \frac{x'}{f'} = \frac{x}{z} \qquad \frac{y'}{f'} = \frac{y}{z}$$

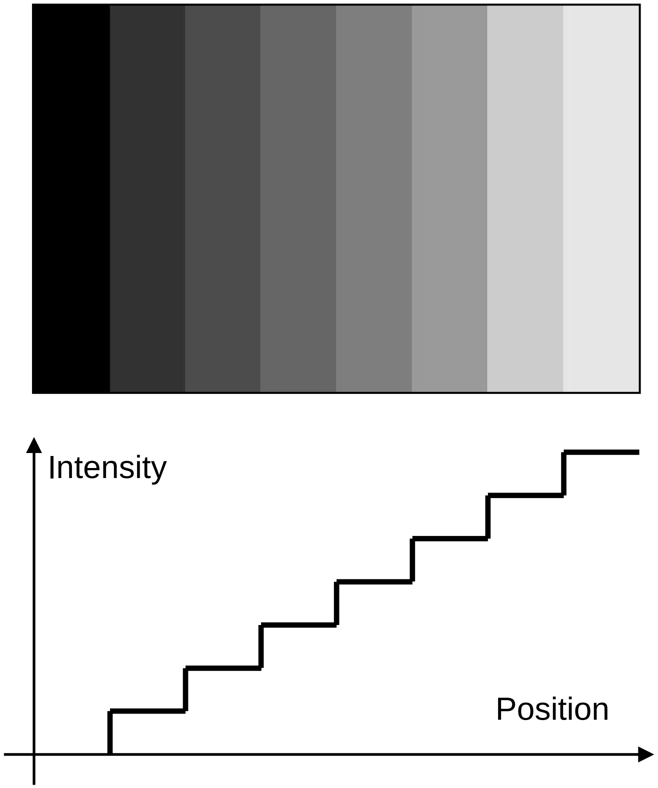
Simple Image Model

- Image as a 2D light-intensity function

$$f(x, y)$$

- Continuous
- Non-zero, finite value

$$0 < f(x, y) < \infty$$

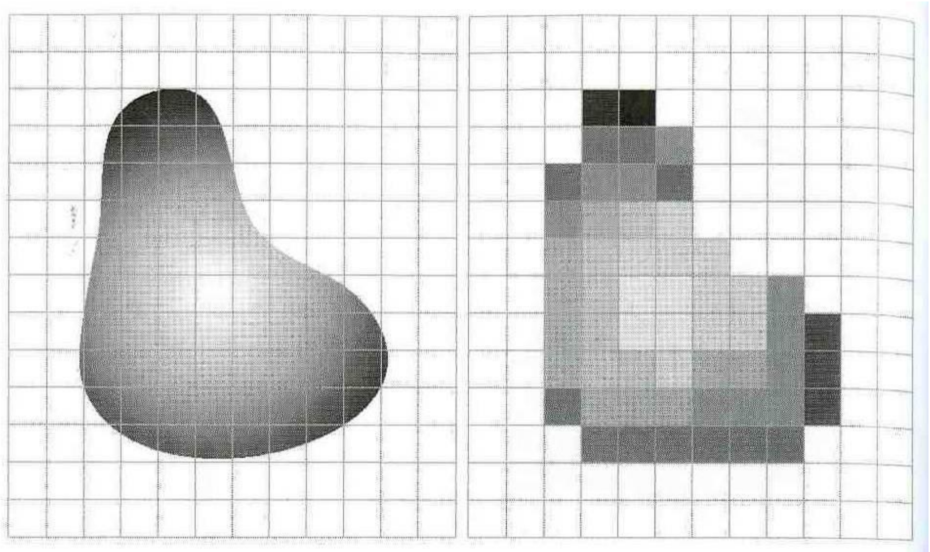


[Gonzalez & Woods]

Analog to Digital

The scene is:

- **projected** on a 2D plane,
- **sampled** on a regular grid, and each sample is
- **quantized** (rounded to the nearest integer)

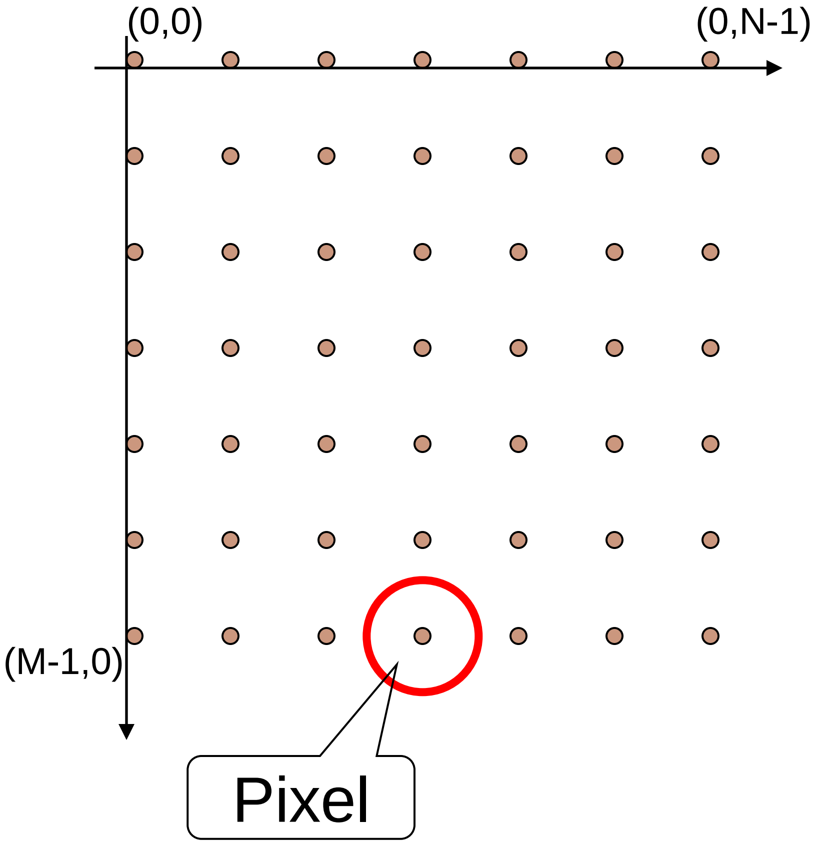


$$f(i, j) = \text{Quantize}\{ f(i\Delta, j\Delta) \}$$

Images as Matrices

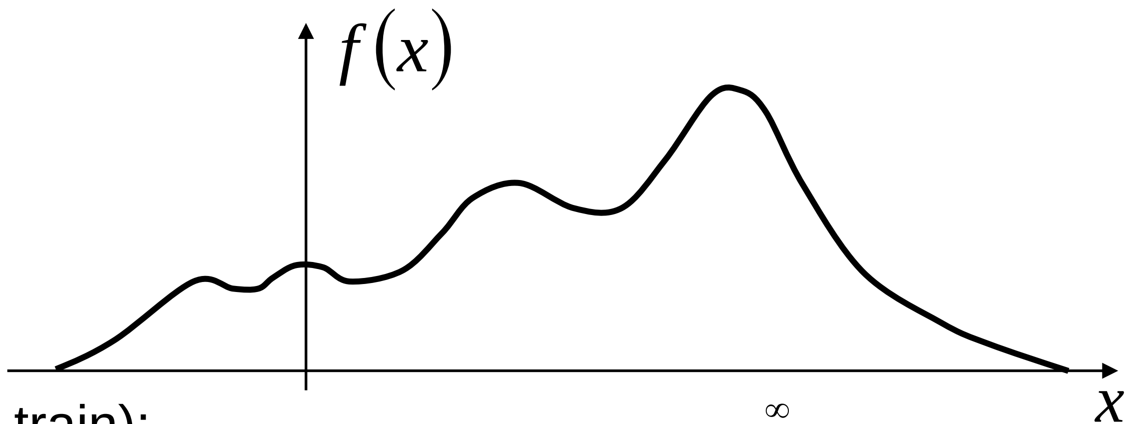
- Each point is a pixel with amplitude:
  - f(x,y)
- An image is a matrix with size N x M

M = [(0,0) (0,1) …
[(1,0) (1,1) …
…



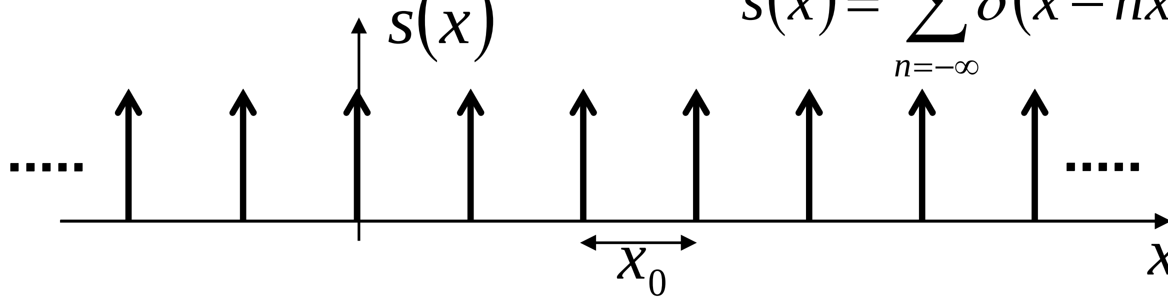
Sampling Theorem

Continuous signal:



Shah function (Impulse train):

$$s(x) = \sum_{n=-\infty}^{\infty} \delta(x - nx_0)$$



Sampled function:

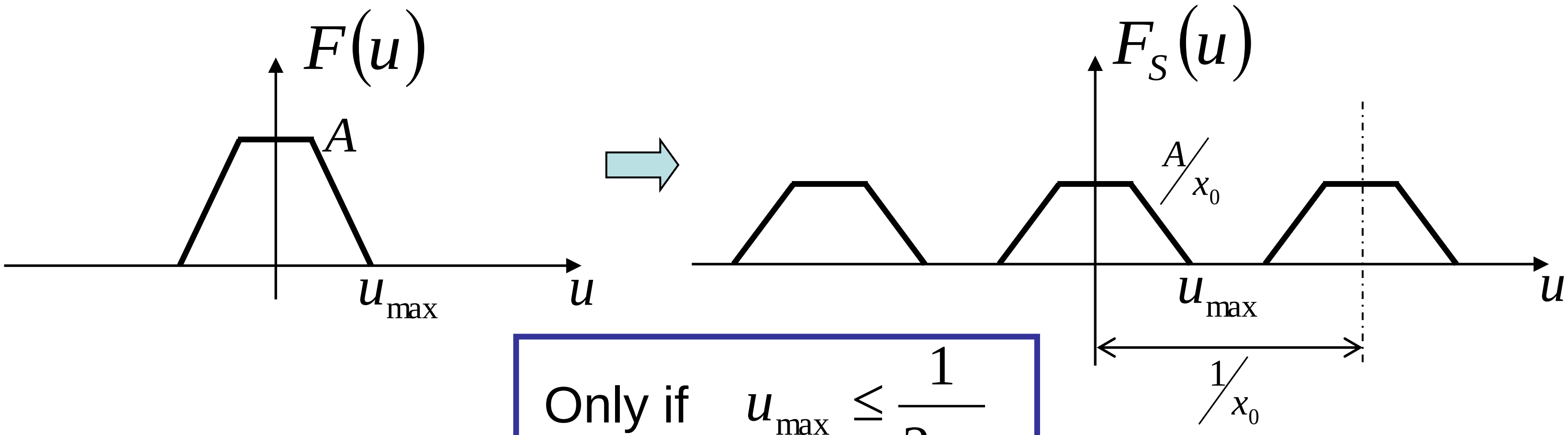
$$f_s(x) = f(x)s(x) = f(x)\sum_{n=-\infty}^{\infty} \delta(x - nx_0)$$

Sampling Theorem

Sampled function: $$f_s(x) = f(x)s(x) = f(x)\sum_{n=-\infty}^{\infty}\delta(x - nx_0)$$

Sampling frequency $\frac{1}{x_0}$

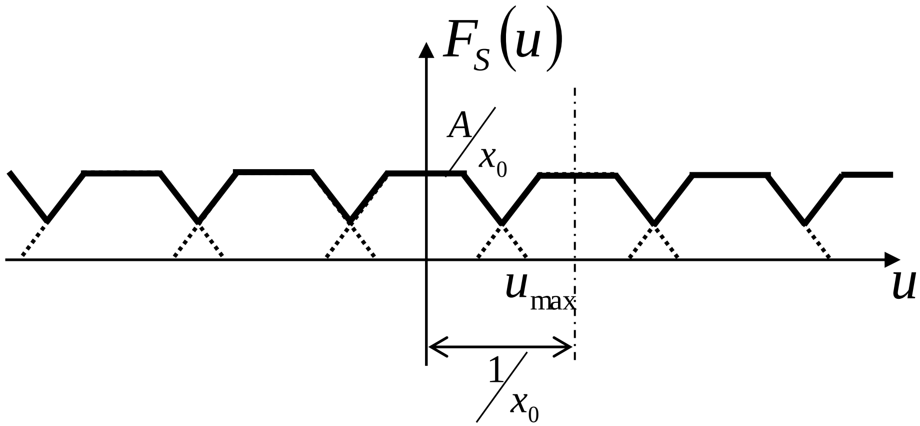
$$F_S(u) = F(u) * S(u) = F(u) * \frac{1}{x_0}\sum_{n=-\infty}^{\infty}\delta\left(u - \frac{n}{x_0}\right)$$



Only if $u_{\max} \leq \frac{1}{2x_0}$

Nyquist Theorem

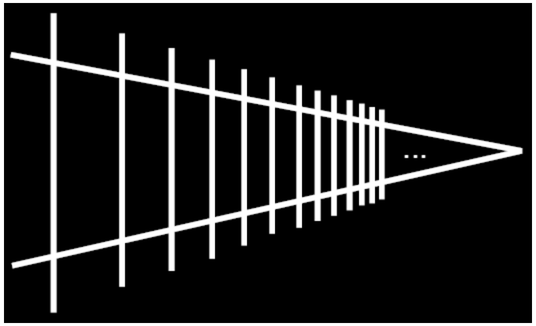
If $u_{\max} > \frac{1}{2x_0}$



Aliasing

Sampling frequency must be greater than $2u_{\max}$

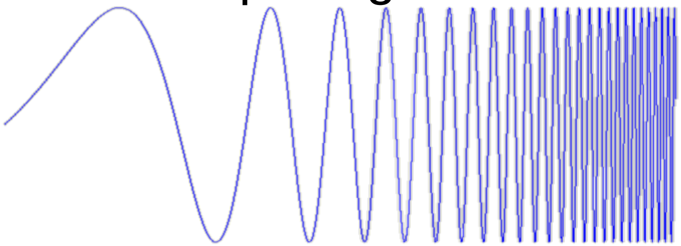
Aliasing



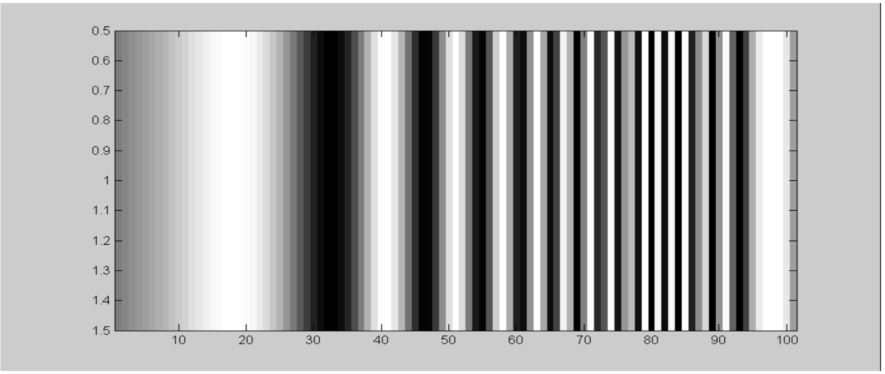
Picket fence receding into the distance will produce aliasing…

WHY?

Input signal:



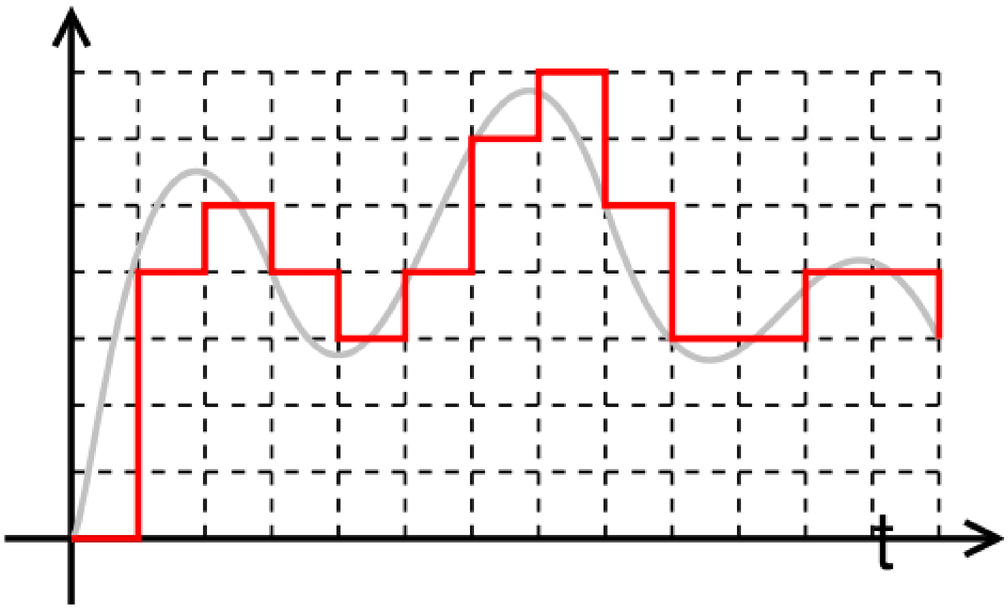
Matlab output:




```
x = 0:.05:5;  imagesc(sin((2.^x).*x))
```

Quantization

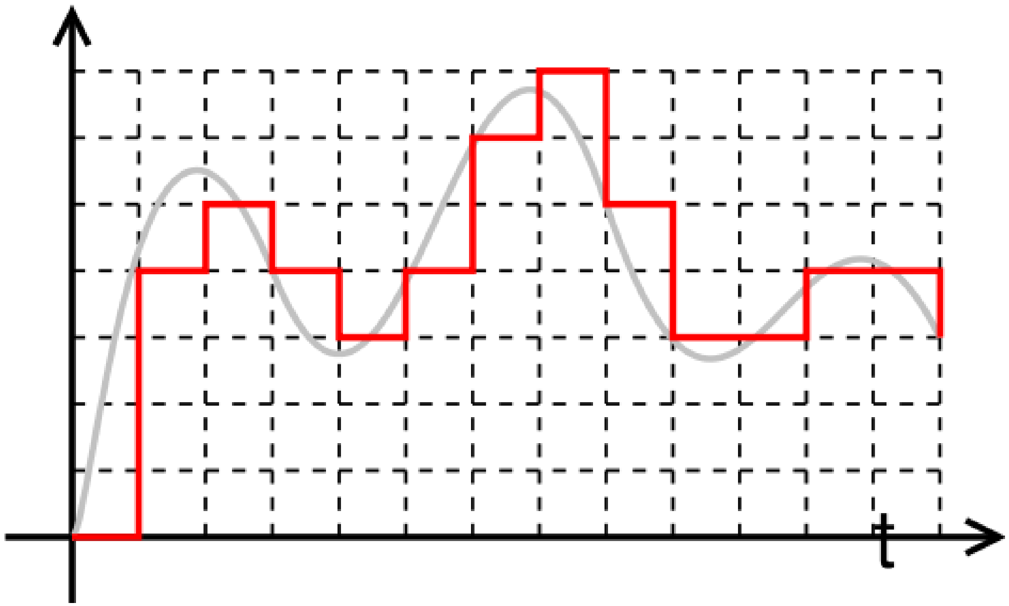
- Analog: $0 < f(x, y) < \infty$
- Digital: Infinite storage space per pixel!
- Quantization



Quantization Levels

- G - number of levels
- m – storage bits
- Round each value to its nearest level

$$G = 2^m$$



Effect of quantization

Effect of quantization

Image Size

- Storage space
  - Spatial resolution: N x M
  - Quantization: m bits per pixel
  - Required bits b:

$$b = N \times M \times m$$

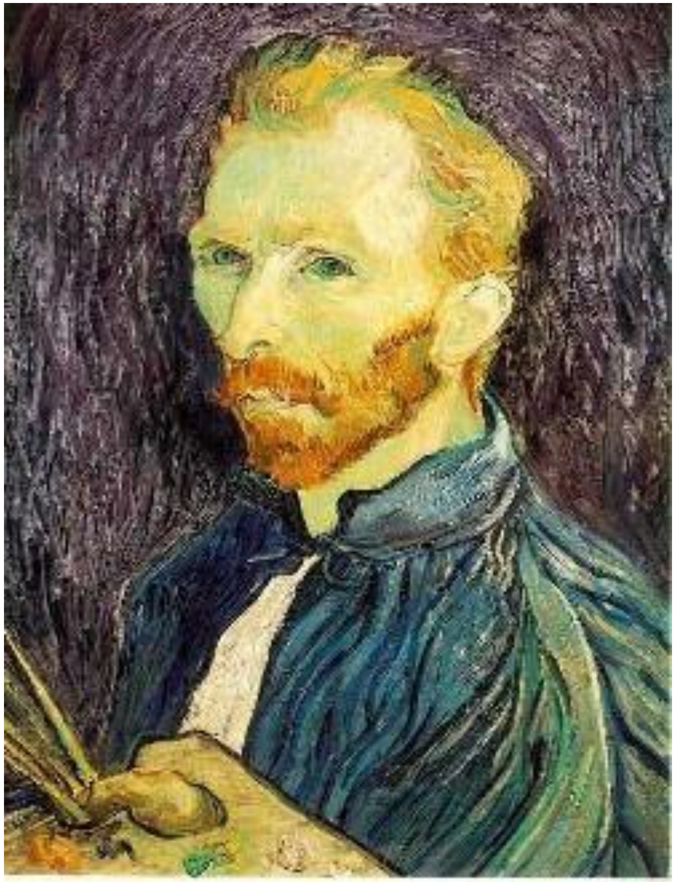
- Rule of thumb:
  - More storage space means more image quality

Image Scaling

This image is too big to fit on the screen. How can we reduce it?

How to generate a half-sized version?

Sub-sampling

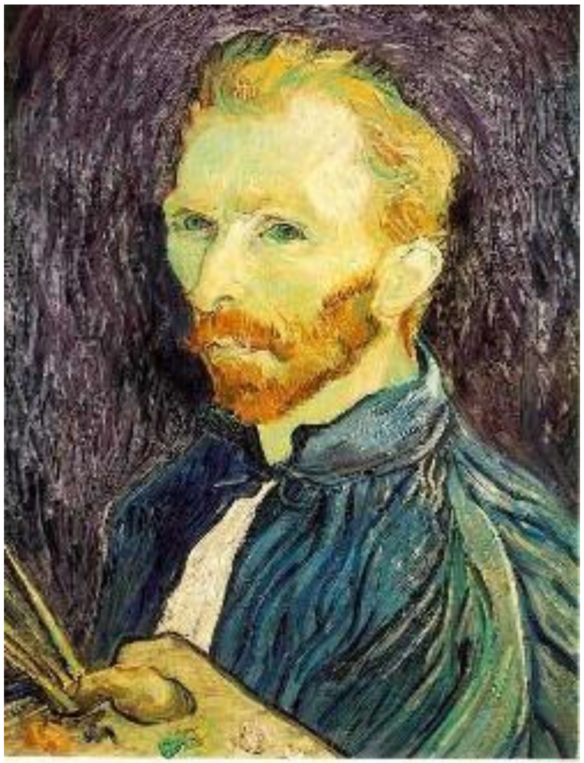


1/4

1/8

Throw away every other row and column to create a 1/2 size image
- called *image sub-sampling*

Sub-sampling



1/2

1/4 (2x zoom)

1/8 (4x zoom)

Topic: Data structures for digital images

- Sampling and quantization
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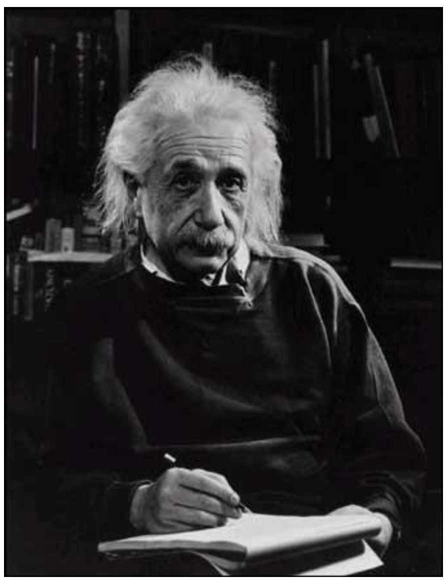
Data Structures for Digital Images

- Are there other ways to represent digital images?



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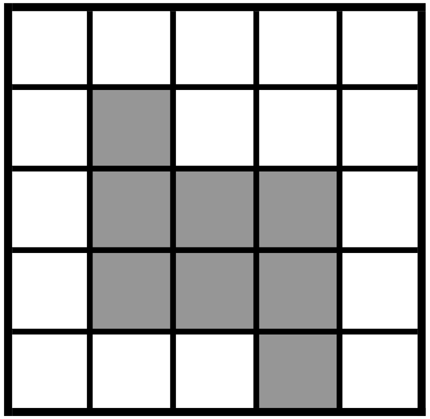
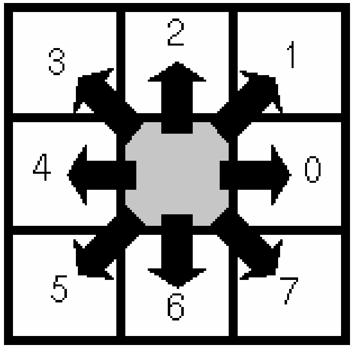
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

What a computer sees

Chain codes

- Chains represent the borders of objects.
- Coding with *chain codes*.
  - Relative.
  - Assume an initial starting point for each object.
- Needs segmentation!



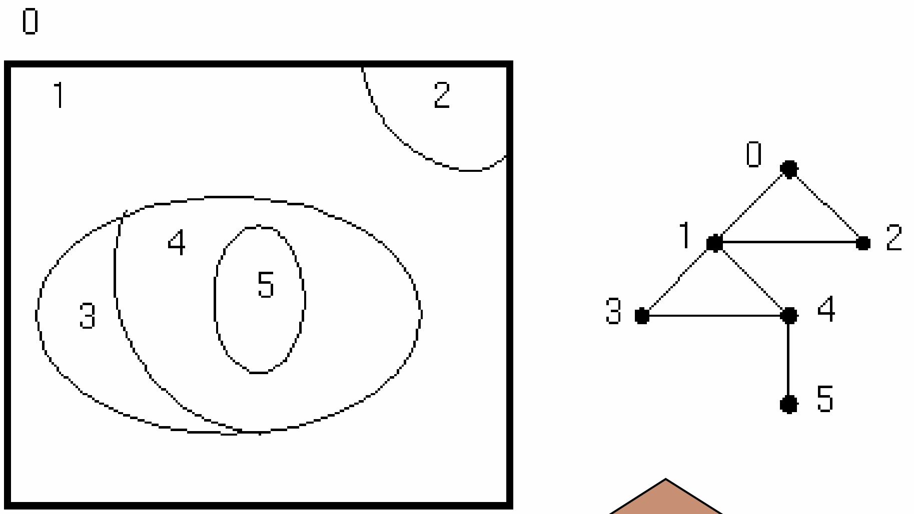


Freeman Chain Code

Using a Freeman Chain Code and considering the top-left pixel as the starting point:
70663422

Topological Data Structures

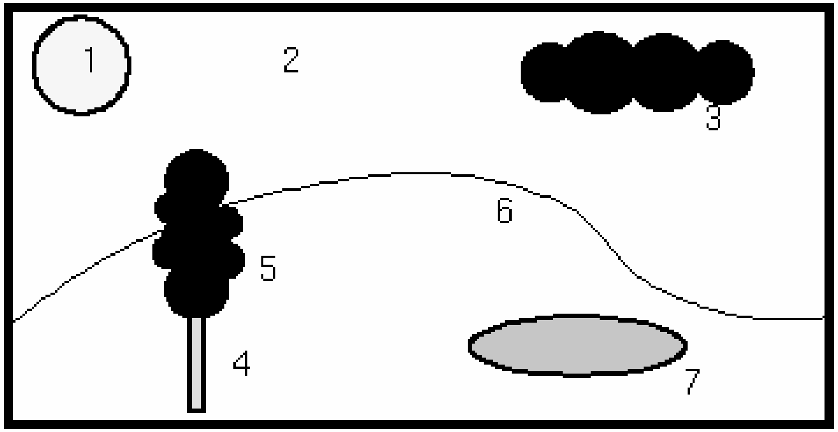
- *Region Adjacency Graph*
  - **Nodes** - Regions
  - **Arcs** – Relationships
- Describes the elements of an image and their spatial relationships.
- Needs segmentation!



Region Adjacency Graph

Relational Structures

- Stores relations between objects.
- Important semantic information of an image.
- Needs segmentation and an image description (features)!



No.	Object name	Colour	Min. row	Min. col.	Inside
1	sun	white	5	40	2
2	sky	blue	0	0	-
3	cloud	grey	20	180	2
4	tree trunk	brown	95	75	6
5	tree crown	green	53	63	-
6	hill	light green	97	0	-
7	pond	blue	100	160	6

Relational Table

Resources

- Szeliski, “Computer Vision: Algorithms and Applications”, Springer, 2011
  – Chapter 2 – “Image Formation”