The Electromagnetic Spectrum and Images

We are familiar with visual light images (photographs), but images can be made from almost any form of EM radiation.

From Wikipedia
Types of Images

- Radar imaging (radio waves)
- Magnetic Resonance Imaging (uses radio waves)
- Microwave imaging
- Infrared imaging
- Photographs
- Ultraviolet imaging telescopes
- X-rays and Computed Tomography
- Positron emission tomography (gamma rays)
- Ultrasound (not EM waves)
The Pinhole Camera
Projective Geometry of the Pinhole Camera

Gives a relationship between coordinates in the 3D world, $X, Y, Z$, and the corresponding coordinates to which they are projected onto the imaging plane, $x, y$. Depends on the focal length, $f$.

$$x = -\frac{f}{Z} X, \quad y = -\frac{f}{Z} Y$$
Camera Obscura

- Uses a pinhole camera to project image into a dark box or room
- In Latin “Camera” = room, “Obscura” = dark
- Pinhole camera first described by the ancient Chinese and Greeks (roughly 400-300 BC)
- First working camera obscura built by Ibn al-Haytham (around 1000 AD)
The Thin Lens
Images as Functions

We can think of the intensity of light falling on the imaging plane as a function of position on that plane.

Let $\Omega \subset \mathbb{R}^2$ be the image domain. Then an image is a function

$$I : \Omega \rightarrow \mathbb{R}$$

This is an idealistic mathematical model of an image.
Images as Functions: Example

A simple image

Image function as a height field
Spatial Sampling

We cannot record (or store) a continuum of values on the imaging plane. So, a finite number of sensors are arranged in a grid.
Spatial Sampling

We can think of spatial sampling as multiplication of a continuous signal with a comb function.
Quantization

We also have to discretize the output intensity $I(u, v)$ to store digitally. This is an analog-to-digital conversion.
Images as Discrete Functions

After spatial sampling and quantization, an image is a discrete function. The image domain $\Omega$ is now discrete:

$$\Omega \subset \mathbb{N}^2,$$

and so is the image range:

$$I : \Omega \rightarrow \{1, \ldots, K\},$$

where $K \in \mathbb{N}$. 
Representing an Image

The data structure for an image is simply a 2D array of values. The values in the array can be any datatype (bit, byte, int, float, double, etc.)