

Introduction to Digital Image Processing

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Alan C. Bovik

The University of Texas at Austin

We are in the middle of an exciting period of time in the field of image processing. Indeed, scarcely a week passes where we do not hear an announcement of some new technological breakthrough in the areas of digital computation and telecommunication. Particularly exciting has been the participation of the general public in these developments, as affordable computers and the incredible explosion of the World Wide Web have brought a flood of instant information into a large and increasing percentage of homes and businesses. Indeed, the advent of broadband wireless devices is bringing these technologies into the pocket and purse. Most of this information is designed for *visual* consumption in the form of text, graphics, and pictures, or integrated *multimedia* presentations. *Digital images* are pictures that have been converted into a computer-readable binary format consisting of logical 0s and 1s. Usually, by an image we mean a still picture that does not change with time, whereas a video evolves with time and generally contains moving and/or changing objects. This *Guide* deals primarily with still images, while a second (companion) volume deals with moving images, or videos. Digital images are usually obtained by converting continuous signals into digital format, although “direct digital” systems are becoming more prevalent. Likewise, digital images are viewed using diverse display media, included digital printers, computer monitors, and digital projection devices. The frequency with which information is transmitted, stored, processed, and displayed in a digital visual format is increasing rapidly, and as such, the design of engineering methods for efficiently transmitting, maintaining, and even improving the visual integrity of this information is of heightened interest.

One aspect of image processing that makes it such an interesting topic of study is the amazing diversity of applications that make use of image processing or analysis techniques. Virtually every branch of science has subdisciplines that use recording devices or sensors to collect image data from the universe around us, as depicted in Fig. 1.1. This data is often multidimensional and can be arranged in a format that is suitable for human viewing. Viewable datasets like this can be regarded as images and processed using established techniques for image processing, even if the information has not been derived from visible light sources.

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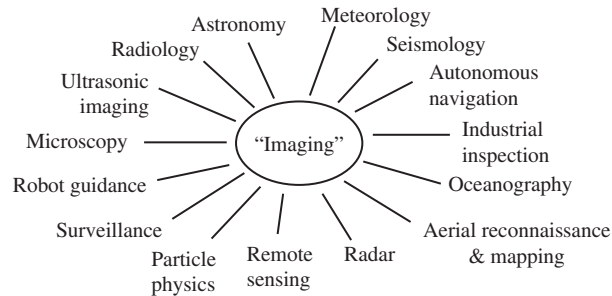


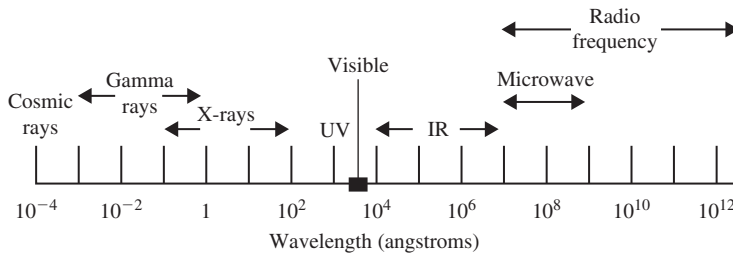
FIGURE 1.1

Part of the universe of image processing applications.

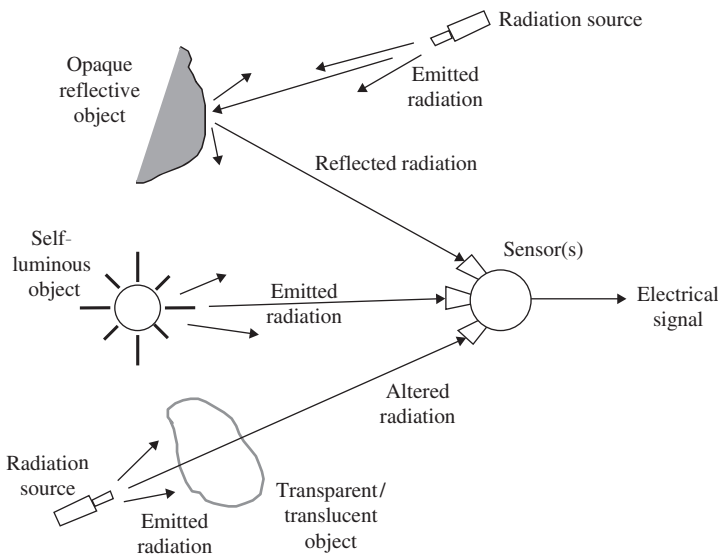
1.1 TYPES OF IMAGES

Another rich aspect of digital imaging is the diversity of image types that arise, and which can derive from nearly every type of radiation. Indeed, some of the most exciting developments in medical imaging have arisen from new sensors that record image data from previously little used sources of radiation, such as PET (positron emission tomography) and MRI (magnetic resonance imaging), or that sense radiation in new ways, as in CAT (computer-aided tomography), where X-ray data is collected from multiple angles to form a rich aggregate image.

There is an amazing availability of radiation to be sensed, recorded as images, and viewed, analyzed, transmitted, or stored. In our daily experience, we think of “what we see” as being “what is there,” but in truth, our eyes record very little of the information that is available at any given moment. As with any sensor, the human eye has a limited bandwidth. The band of electromagnetic (EM) radiation that we are able to see, or “visible light,” is quite small, as can be seen from the plot of the EM band in Fig. 1.2. Note that the horizontal axis is logarithmic! At any given moment, we see very little of the available radiation that is going on around us, although certainly enough to get around. From an evolutionary perspective, the band of EM wavelengths that the human eye perceives is perhaps optimal, since the volume of data is reduced and the data that is used is highly reliable and abundantly available (the sun emits strongly in the visible bands, and the earth’s atmosphere is also largely transparent in the visible wavelengths). Nevertheless, radiation from other bands can be quite useful as we attempt to glean the fullest possible amount of information from the world around us. Indeed, certain branches of science sense and record images from nearly all of the EM spectrum, and use the information to give a better picture of physical reality. For example, astronomers are often identified according to the type of data that they specialize in, e.g., radio astronomers and X-ray astronomers. Non-EM radiation is also useful for imaging. Some good examples are the high-frequency sound waves (ultrasound) that are used to create images of the human body, and the low-frequency sound waves that are used by prospecting companies to create images of the earth’s subsurface.

**FIGURE 1.2**

The electromagnetic spectrum.

**FIGURE 1.3**

Recording the various types of interaction of radiation with matter.

One commonality that can be made regarding nearly all images is that radiation is emitted from some source, then interacts with some material, then is sensed and ultimately transduced into an electrical signal which may then be digitized. The resulting images can then be used to extract information about the radiation source and/or about the objects with which the radiation interacts.

We may loosely classify images according to the way in which the interaction occurs, understanding that the division is sometimes unclear, and that images may be of multiple types. Figure 1.3 depicts these various image types.

Reflection images sense radiation that has been reflected from the surfaces of objects. The radiation itself may be ambient or artificial, and it may be from a localized source

Chapter extract

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