Chapter 1
Introduction

Images have always served as an inspiration to perceive our environment. Naturalism in art, supported in the sixteenth century by the knowledge of the perspective projection, was replaced in the nineteenth century by the technique of registering perspective images as photographs. Photographs not only initiated the transition to modernity in art but soon were used for solving engineering tasks, such as the 3D mensuration of buildings for preserving cultural heritage (Albertz, 2001). Today, digital images are omnipresent and used as a matter of course for documentation, communication, reconnaissance, and surveillance. Professional application domains are medicine, industrial inspection, quality control, and mapping and remote sensing. Computers not only serve as image storage and allow image processing but also enable image analysis and interpretation. Early examples are barcode readers; late examples, 3D models of complete cities as in Google Maps or Microsoft's Bing Map.

This book is about concepts and methods for developing computer vision systems for automatically analysing images, with a focus on the main application areas of photogrammetry, specifically mapping and image-based metrology.

Photogrammetry is the science and technology of obtaining information about the physical environment from images, with a focus on applications in mapping, surveying and high-precision metrology. The aim of photogrammetry is to provide automated or semi-automated procedures for these engineering tasks, with emphasis on a specified accuracy, reliability and completeness of the extracted information.

Computer vision, a science and technology of obtaining information about the physical environment from images, does not focus on specific applications. On the contrary, its roots are in the area of what is called artificial intelligence, which aims at mimicking intelligent human behaviour. It has deep links to cognitive science via the analysis of the visual system of animals and humans. As such it is a special part of artificial intelligence, addressing among other things the development of systems, e.g., robots, which mimic the cognitive capabilities of natural systems having vision sensors. Such sensors may be cameras or video cameras, laser scanners or tomographic sensors, as long as they yield a dense description of the object.

Photogrammetric computer vision comprises photogrammetric theories, methods and techniques related to computer vision problems and relevant for automatically solving tasks in mapping and metrology using software systems and the necessary tools for design and evaluation of the results. As such it is intimately linked with methods from mathematics, statistics, physics, and computer science. It is closely coupled especially to methods in computational geometry, image processing and computer graphics (cf. Fig. 1.1). As photogrammetry can be seen as a part of remote sensing, the mentioned aspects are also valid for analysing satellite images or images with many bands of the physical spectrum.

This book is the first of two volumes on photogrammetric computer vision. This first volume addresses all aspects of statistically founded geometric image analysis, the second volume will focus on methods of image processing, analysis, interpretation. Both volumes address the mathematical concepts for developing vision software systems. They do not

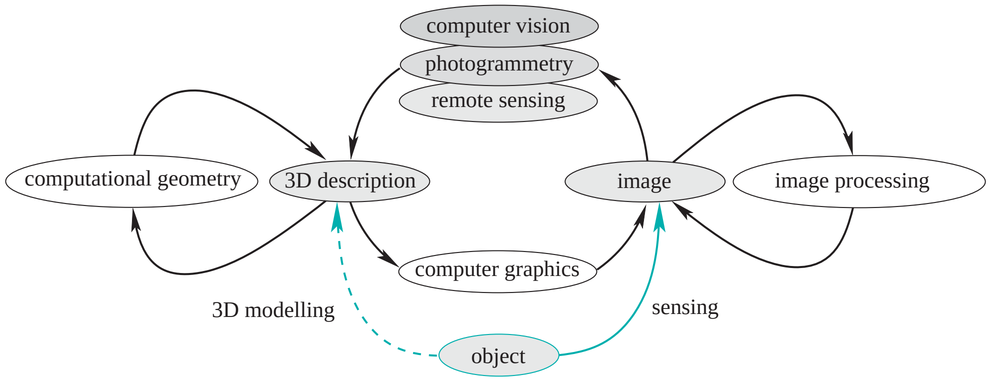

Fig. 1.1 Computer internal processing of 3D descriptions of objects and their images touches several disciplines: *image processing* (right) transforming images to images, with goals such as noise suppression, coding, warping or generating computer tomographic images; *computational geometry* (left) transforming 3D objects, with tasks such as constructing 3D objects in a CAD system, ray tracing or path planning; *computer graphics* (bottom) generating realistic images from 3D scenes consisting of objects – mimicking the process of physical *sensing* – with tasks such as photo-realistic rendering, computer animation, or visualization of physical phenomena. The inverse process deriving scene information from images is addressed by *computer vision, photogrammetry, or remote sensing* (top) with tasks such as understanding videos, generating maps from aerial images or inferring environmental parameters from satellite images – all supporting 3D modelling

deal with the hardware technology as such, e.g., the man–machine interfaces for supporting practical mapping tasks. However, to perform image analysis, they use knowledge about the physics of the image formation process, in the context of this volume specifically about the *physical and geometrical structure of cameras and laser range scanners*.

In the following we illustrate classical tasks of photogrammetric computer vision, and elaborate on our view of modelling for automatic image analysis, which motivates the structure of the book and suggests how to use it.

1.1 Tasks for Photogrammetric Computer Vision

1.1.1 Data Capture for GIS

The generation of topographic maps since the 1930s is based on aerial images, taken with specialized cameras on aeroplanes from altitudes up to ten kilometres. The maps first were manually drawn on paper; today the still mainly manually acquired information is stored in geoinformation systems, at whose core is a spatial database. The information is used, among other things, for navigation systems or urban planning (cf. Fig. 1.2, top row). Since the 1970s satellite scanners provide digital data from space with resolutions on the ground between a kilometre for meteorological purposes and below a meter for cartographic purposes. For a few decades mobile mapping systems, which acquire images and also laser scan data from moving vehicles, are used to regionally obtain high-resolution 3D models, especially of cities (Fig. 1.2, second row). Only recently have unmanned aerial vehicles reached the civil market, supporting local mapping on demand.

The most elementary product derived by photogrammetry is the elevation model, in analogue maps presented by contour lines, since the 1980s realized as the digital elevation model (DEM). It refers to what is called the topographic surface, i.e., the bare ground without buildings and vegetation (Fig. 1.2, third row). Automatic methods based on aerial images in a first instance derive the visible surface represented as the digital surface model