Chapter 1
Mobile Robot Navigation

Abstract. This chapter introduces the basic concepts of autonomous navigation of mobile robots and the utility of using vision as the sensing mechanism in achieving the desired objectives. The chapter discusses the broad categories of vision-based navigation in indoor and outdoor environments. Different prominent directions of research in this context are introduced and also different broad modalities of obstacle detection and avoidance are presented.

1.1 Autonomous Mobile Robot Navigation

Advances in recent technologies in the area of robotics have made enormous contributions in many industrial and social domains in recent times. Nowadays numerous applications of robotic systems can be found in factory automation, surveillance systems, quality control systems, AGVs (autonomous guided vehicles), disaster fighting, medical assistance etc. More and more robotic applications are now aimed at improving our day-to-day lives, and robots are now caught in sight more often than ever before performing various tasks in disguise [1]. For many such applications, autonomous mobility of robots is a mandatory key issue [100]. Autonomous mobile robots are robots which can perform desired tasks in structured or unstructured environments without continuous human guidance. A fully autonomous mobile robot has the ability to:

- Gain information about the environment.
- Work for an extended period without human intervention.
- Move either all or part of itself throughout its operating environment without human assistance.
- Avoid situations that are harmful to people, property, or itself, unless those are part of its design specifications.

An autonomous mobile robot may also learn or gain new capabilities like adjusting strategies for accomplishing its task(s) or adapting to changing surroundings.

1.2 Why Vision in Navigation?

Vision is the sense that enables us, humans, to extract information about the physical world, and, appropriately, it is the sense that humans rely on the most. In recent past, computer vision techniques capable of extracting such information are
continuously being developed and refined. Vision processing is computationally intensive, but as faster and lower priced processors being developed, the development of real-time vision-based navigation systems for mobile robots is becoming a reality for a variety of complicated jobs and more research works are being focused in this domain now, than ever before [100].

The other sensors that are used for navigation include infrared sensors, sonar sensors, laser range finders, the position sensing device (PSD) sensors and inertial sensors. Infrared sensors have limited usage; they are very often used as proximity detectors and the main shortcoming of using them as range finders lies in their limited range and their susceptibility to ambient light interference. IR sensors are also known for their non-linear behavior and their reflectance dependency on the surface of a target [2]. Sonar sensors are computationally affordable and their data are simple to read, but the reliability of their data is low due to the environmental disturbances. The sonar range finder measures the distance to an object, but has poor angular resolution due to its wide beam width [3]. Laser range finders provide better reliability, instantaneous measurement, superior range accuracy, and precise angular resolution than sonar, with finer directional resolution, but at much higher cost. Laser-based sensors can extract information more than distance only. For example, laser scanners are often used to extract topological information making the best use of its ability to identify the textures of an object’s surface and its precise range approximation. The laser range finder has a disadvantage that the scan may be prone to missing transparent objects, such as glasses and windows. Inertial navigation sensors such as accelerometers and gyroscopes provide orientation and trajectory measurements of the moving vehicles, but provide no information about the obstacles in the environment that the vehicle is traversing. GPS is one of the most popular aiding tools in navigation systems in use today. GPS provides real time absolute or relative position data, but the accuracy and bandwidth are limited compared to the typical requirements of relative proximity operation. The performance of GPS can suffer by occlusion of line-of-sight to satellites and their accuracy and update rate may be slow [4]. These range-based sensors have difficulties in detecting small or flat objects on the ground. These sensors are also unable to distinguish between different types of ground surfaces. While small objects and different types of grounds are difficult to detect with range-based sensors, they can in many cases be easily detected with a passive sensor, like camera. A vision system is considered as a passive sensor and has the fundamental advantages over the active sensors that are considered as active sensors such as infrared, laser, and sonar sensors [5]. Passive sensors such as cameras do not alter the environment by emitting lights or waves in acquiring data, and also the obtained image contains more information (i.e. substantial, spatial and temporal information) than active sensors. All these sensors acquire less information about the physical environment than a camera can potentially, and with the continued growth of faster and cheaper computing power, that potential is now being tapped for designing real-world vision based navigational systems. Cameras are cheap to purchase, with even the most expensive cameras being relatively affordable. Hence vision as a sensing mechanism for mobile robots offers very attractive potential for solution.