Robot Navigation Using Panoramic Landmark Tracking

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Abstract

A vision based navigation system is presented for determining a mobile robot's position and orientation using panoramic imagery. Omni-directional sensors are useful in obtaining a 360° field of view, permitting objects in the vicinity of a robot to be imaged simultaneously. Recognizing landmarks in a panoramic image from an a priori *model of distinct features in an environment allows a robot's location information to be updated. A system is shown for tracking vertex and line features for omni-directional cameras constructed with* catadioptric *(containing both mirrors and lenses) optics. With the aid of the* Panoramic Hough Transform, *line features can be tracked without restricting the mirror geometry to that which satisfies the single viewpoint criteria. Two paradigms for landmark tracking are explored, with experiments shown with synthetic and real images reported. A working implementation on a mobile robot is shown.*

1 Introduction

One fundamental component for an autonomous mobile robotic platform is to determine its position and orientation with respect to its environment. Example systems use sonar sensors, motor odometry and radio beacons [3]. A passive vision-based system would be very advantageous, and increase the practical utility and scalability of mobile robotics. Hager and Rasmussen define a framework for robot navigation using standard perspective cameras [11, 14]. If this vision system was panoramic, objects all around the robot could be used for finding and updating the position estimate.

The paradigm of an agent translating along a horizontal plane and rotating about a vertical axis, in a space defined and filled with rectilinear polyhedral objects is a reasonable assumption for a mobile robot operating in a man-made environment. Indeed most indoor scenes can be well defined by the primitives of horizontal and vertical lines, corners where such line edges meet, and rectangular surfaces with only horizontal and vertical edges.

Thus we define a framework for creating a passive vision-based navigation system as that of iteratively predicting the location of a prominent geometric feature composed of horizontal and vertical lines, tracking the location of the feature in a panoramic image, and aggregating a number of such observations to arrive at a new position and orientation estimate. We are restricting the problem to that of a mobile agent with motion possible only along the horizontal axis, reducing the dimensions of navigation data to three, two for position and one for orientation. The presence of an *a priori* model of prominent landmarks for predicting trackable features is assumed.

Omni-directional viewing would require many standard narrow field of view cameras, or one panoramic camera. A *catadioptric* optical system is one that uses both lens and mirror components in the optical path, and can be used to capture a 360° field of view around a mobile robot. Basu [2], and others [13, 16, 17, 4, 5] have demonstrated such catadioptric panoramic systems. An example is shown in Fig. 1(left). If a convex, radially symmetric mirror, lens(es) or pinhole and a planar image plane are all mounted along one vertical axis, then a panoramic view can be captured as shown in Fig. 1(right). Such a system has the advantages of processing only one image, and with this image being continuous, not having to deal with discontinuities at the boundaries of views as a ring of conventional cameras would introduce.

Such a view permits the capture of a panoramic view, but with the added challenge of finding and tracking objects in a non-perspective projection. Panoramic catadioptric cameras are not necessarily even cylindrical projections, and locating and tracking features (especially lines) introduces challenges from tracking in more traditional perspective view imagery.

The first positioning method demonstrated assumes a cylindrical projection, or at least a quasi- cylindrical view