# Chapter 6
# Visual Feedback for Nonholonomic Mobile Robots:
## Homography Based Approach

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## ABSTRACT

*In this chapter, we describe a homography approach to vision based feedback for nonholonomic mobile robots control. Differently than other approaches based on homography or fundamental matrix, our method has been developed to be robust to reference features loss, during the robot movement. This allows us to implement an arbitrary control law without the need of a teach-by-showing stage. In the chapter, the use of a stereo camera system to improve the observer accuracy and to perform an auto-calibration of the stereo-head pose is investigated. Experimental results are provided to show the performances of the proposed system state estimation, using an eye-in-hand mobile robotic platform.*

## INTRODUCTION

The classical approach in visual servoing is the one of controlling some features evolution in the image space. No constraints on the system state evolution are taken into account. In the last years, the researchers start to cope with the problem of controlling nonholonomic systems like mobile robots and new approaches to visual servoing have been investigated.

Mobile robots have to navigate in dynamic environments to execute a given task while avoiding obstacles and keeping on localizing themselves. Many sensors (for instance, encoders, laser finders, ultrasonic sensors) are classically used to execute navigation in man-made environments. However, most of these sensors are too expensive to be applied to low-cost service robotics. Vision is a very rich data source. A single sensor can be used to infer many pieces of information about the environment in which

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the robot is moving, while supporting the autonomous navigation. There are a lot of different works in literature about this topic. A brief survey follows.

The first work to cite is certainly (Faugeras & Lustman, 1988). Here it is addressed the problem of structure from motion in a piecewise planar environment. The piecewise planar environment provides a powerful constraint on the kind of matches that exist between two images of the scene, when the camera motion is unknown.

A pioneer work on visual control for robot navigation is (Guerrero, 2001). It describes the use of an uncalibrated monocular vision system based on lines. It uses the epipolar and visibility constraints to compute the current heading and a depth map in steps to collision unit.

A family of solutions in dynamic object detection from mobile platforms assumes restricted camera/robot motion in the attempt to simplify the egomotion estimation and object detection problem. In (Franke & Heinrich, 2002), the author assumes purely forward camera motion and detects moving objects as outliers that violate this motion model. Effects of rotational egomotion are canceled using a-priori trained rotational motion templates. The motion model is less restrictive in (Ke & Kanade, 2003), where 3 DOF robot motion is estimated.

In (Talukder & Matthies, 2004), it is described a method to robustly estimate 6-DOF robot egomotion in the presence of moving objects using dense flow and dense stereo. The proposed solution combines dense stereo with dense optical flow and yields an estimate of object/background motion at every pixel; this increases the likelihood of detecting small/distant objects or those with low texture where feature selection schemes might fail.

In (Liang et al., 2004), the ground plane is used as reference feature. It is presented how it is possible to determine the height of corner features above the ground plane in order to support visual navigation functions for mobile robots.

In (Simond & Rives, 2004), a method to compute the relative motion of an uncalibrated stereo head is described. The method is based on the extraction of significant features by the road.

In (Dao et al., 2005), it is proposed an algorithm that estimates valid planar regions for a mobile robot to pass. The algorithm can eliminate illegal planar areas in the input image by using the labeling and filtering based on the size of each blob. It is based on assumptions that the ground floor is almost flat and the image plane is perpendicular to the ground floor, 3-D pose determination is solved by a linear or quadratic equation.

In (Comport, 2007) a quadrifocal tracking methodology is presented. The idea is to estimate the trajectory without the need of identifying and tracking intermediate level features. The approach seems to be very robust and efficient.

One of the first works that investigates the use of homographies to support mobile robots visual navigation is (Liang, 2002). In that paper, it is studied how planar homographies can be extracted from two points correspondences and how to extract camera rotation from homographies.The first work which considers directly the elements of the homography to do control, without requiring the homography decomposition is (Guerrero, 2005). From this short presentation of the (huge) literature on the visual aided navigation, let's come back to talk about control problems.

It is well-known that the control execution is affected by the accuracy of the feedback measures. Odometry errors or slipping and mechanical drifts may make the desired position not to be reached. A visual feedback can avoid this kind of problems and can be effectively used to lead the mobile robot to the desired pose. This means that the same visual sensor used to acquire pieces of information about