

1992 ED Dickmanns. BD Mysliwetz: Recursive 3-D Road and Relative Ego-State Recognition

Abstract—The general problem of recognizing both horizontal and vertical road curvature parameters while driving along the road has been solved recursively. A differential geometry representation decoupled for the two curvature components has been selected. Based on the planar solution of [7] and its refinements, a simple spatio-temporal model of the driving process allows us to take both spatial and temporal constraints into account effectively. The estimation process determines nine road and vehicle state parameters recursively at 25 Hz (40 ms) using four Intel 80286 and one 386 microprocessor. Results with the test vehicle (VaMoRs), which is a 5-ton van, are given for a hilly country road.

Index Terms—Intelligent control, parallel architectures, real-time machine vision, recursive estimation, spatio-temporal modeling, 3-D image sequence processing, visual navigation (of road vehicles).

I. INTRODUCTION

THE SPECIFIC subtask of the general theme of the issue considered in this paper is 3-D road recognition while driving along a road. It is claimed that 3-D scene recognition during motion is easier than with a static camera if some knowledge about the motion behavior of the vehicle carrying the camera, the so-called "ego vehicle," is given. In the present case, it is assumed that the ego vehicle is an ordinary car with frontwheel steering driving on ordinary roads. Taking the known locomotion measured by ordinary odometers or speedometers into account, integration of measurements over time from a single passive monocular 2-D sensor allows motion stereo interpretation in a straightforward and computationally very efficient way.

The capability of road vehicles, which are abundant in our technically developed civilization, to orient themselves and avoid damage by exhibiting safe behavior on their own could considerably reduce the present death toll and economic losses in road traffic in the future. The European project PROMETHEUS aims to develop this technology among other countries. The research on which we report here was one of the pioneering efforts in Germany preceding PROMETHEUS.

Being oriented toward general road networks, the type of scenes investigated are the human-built infrastructure "road," which is standardized to some extent but is otherwise quasi-natural with respect to environmental conditions like lighting including shadows, weather, and possible objects on the road.

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Here, we confine ourselves to just road recognition; beginning work on obstacle detection and relative spatial state recognition using the same methods has been reported in [12].

One of the goals of this research effort is to demonstrate that machine vision systems are able to get along with the infrastructure developed for the human driver and, in addition, to take advantage of most or all of the installations put up for the driver. For this purpose, it seems advantageous to endow the system with the capability of reasoning in space and time and to provide it with a basic "feeling" of how to react with respect to its control inputs over time, given the physical object state and, possibly, the context of a more complex situation. This implies the use of a) implicit knowledge about the motion behavior of objects, as has been developed in the engineering disciplines using dynamical models, on some lower reflex-like behavioral levels and b) explicit knowledge on higher levels for mission-specific decision taking. Contrary to other approaches using an "artificial intelligence" framework for basic spatial scene understanding, a conventional estimation scheme is used here to arrive at a spatio-temporal internal representation by analysis through synthesis.

For the planar case, this method developed in [7], [9], and [10] has shown superior performance with modest computational efforts. It rests on a differential geometry representation of the road skeletal line in the near environment of the vehicle combined with a perspective mapping model based on a Cartesian space representation of the same environment. The essential point is that time is an integral part of this internal representation allowing exploitation of temporal continuity constraints derived from the known motion behavior capabilities of the vehicle and its control input.

This method has been extended in [25] to the general case of roads with both horizontal and vertical curvature. As opposed to more theoretical approaches suggested in [5], [26] and [30], which conceive the problem as a merely static 3-D interpretation of line drawings not taking observer dynamics into account, our approach relies on data fusion from conventionally measured distance traveled (odometer data) and has been successfully implemented and tested in real world experiments with our van.

In the next section, the task to be solved is formulated. Then, image sequence analysis is interpreted as a tele-measurement process with no direct link to the object being measured, and, therefore first requiring object identification. To this end, in the following sections, the 3-D road model, the measurement model, and the egomotion model are given, which are then combined in state transition form for the case of time discrete