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Abstract

This paper describes a laboratory system for recovering the global coordinates of feature points obtained from a moving camera. The prototype includes a stereo vision system combined with an overhead camera, which mimics a GPS receiver. The stereo vision system provides three dimensional feature point coordinates relative to the position of the cameras and the overhead camera provides three-dimensional coordinates of the camera in a "global" coordinate system. The fusion of these data provides three-dimensional feature point coordinates in a fixed origin global coordinate system.

Keywords: Stereo vision, GPS, Data Fusion

1 Introduction

Many applications currently exist that require the position of an arbitrary feature point in a fixed origin coordinate system. A mobile road integrity inspection system may need to log the position of a faulty or obsolete road marking or a pothole. An ordnance surveyor may need to record the location of an object for map reconstruction.

In this paper a system is described that addresses these problems. The system is divided into two main components. The first is a stereo vision system, which is capable of extracting local three dimensional coordinates of a point in the scene. Unfortunately, every time the cameras move, so does the origin of the camera coordinate system so feature points do not have a fixed origin under camera motion.

The second component of the system introduces a fixed origin global coordinate system for feature points identified under arbitrary camera motions. Currently the system is a laboratory prototype consisting of an overhead camera extracting the position and orientation of a small remote controlled mobile stereo vision system. The final system will use a GPS receiver to obtain position information. The moving compass built into many GPS receivers or an inertial navigation sensor will provide orientation information. A transformation of the stereo coordinate systems to this world coordinate system results in the coordinates of feature points in a fixed origin world coordinate system.

Previous work has seen the development of similar systems for navigational purposes. Simon and Becker [1] fused a DGPS sensor and a stereo vision sensor to recover global position of a vehicle to examine road geometry. Rock et al [2] fused a CDGPS sensor and a stereo vision module to aid a helicopter in the tracking of an object. The purpose of the system described in this paper is to provide a mechanism for a road engineer to record global positions on a standard map of faulty road markings identified automatically in a prerecorded image sequence.

A more detailed description and explanation of the system components and techniques is presented in section 2. Some preliminary results obtained form the prototype is presented in Section 3. Section 4 concludes the paper and discusses some future work in the area.

2 System description

This section describes in detail the two components of the system along with their fusion. Section 2.1 describes the stereo component. Section 2.2 describes the navigational component and Section 2.3 describes the fusion of the two.

2.1 Computation of local three-dimensional coordinates of feature points

The apparatus used to compute local three-dimensional coordinates of feature points is shown in figure 2.1. It consists of two SONY XC-77CE CCD camera modules (576 x 768) mounted on a mobile platform which is controlled remotely. The remote control car on which the chassis was obtained was chosen for its slow speed and robust design, it being designed for young children. Video and synchronization signals were connected to the car via a cable harness, (see Figure 1).

Figure 1 Mobile remote controlled stereo vision unit

The model provides a scaled down version of the vehicle-mounted system under development. The baseline of the camera pair is 0.0625. The baseline of the real system is approximately 1.2 meters to allow for ranging of objects a significant distance in front of the vehicle.

Conventional techniques for stereo ranging were used. The epipolar geometry of the cameras is computed from the fundamental matrix [3]. Correlation is conducted along the epipolar lines to facilitate stereo feature point correspondence [4].

2.2 Computation of vehicle coordinates and orientation in global coordinate system

A black enclosure was constructed (3 meters x 2 meters) to serve as a "world" space, (see Figure 2). An overhead camera was placed directly above the enclosure to extract the position and orientation of the mobile unit. A white arrow was placed on top of the mobile unit to facilitate this process. Position is computed as the center of mass of the arrow. Orientation of the arrow marked on the roof of the vehicle was computed using a technique based on the method of least squares [5], (see Figure 3). An alternative approach to identifying orientation would have been to use the Hough Transform.

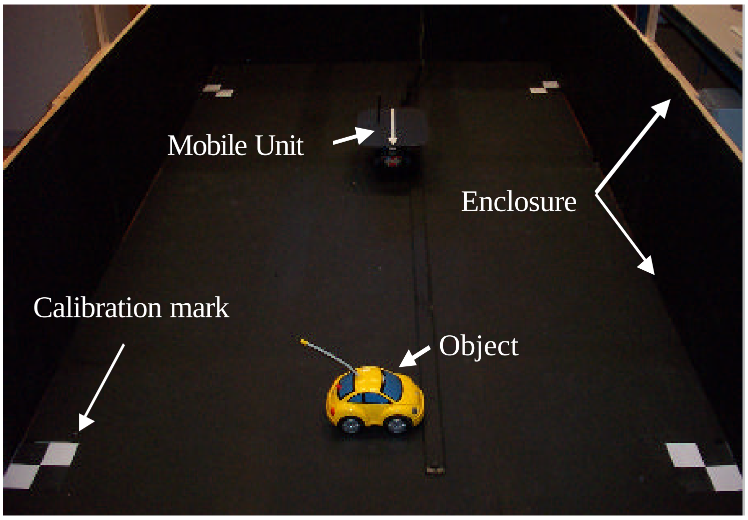


Figure 2 System configuration, showing location of key components

2.3 Fusion of local and global coordinate system

The local and the global coordinate systems are Euclidean. The transformation of the local coordinate axes to the global coordinate axes will give the location of the feature point in the global coordinate system. Let θ be the orientation of the mobile unit. Let **T,** be the position vector of the mobile unit. The rotation matrix for the x and z coordinates is,

$$\mathbf{R} = \begin{bmatrix} \cos\left(\theta - \frac{\pi}{2}\right) & -\sin\left(\theta - \frac{\pi}{2}\right) \\ \sin\left(\theta - \frac{\pi}{2}\right) & \cos\left(\theta - \frac{\pi}{2}\right) \end{bmatrix} \tag{2.1}$$

The factor of $-\pi/2$ was introduced since the direction of the arrow is perpendicular to the baseline direction. The location of the feature point in the global coordinate system is denoted as P_g. The location of the feature point in the local coordinate system is denoted as P_l. P_g can be computed from the transformation,

$$\mathbf{P}_g = \mathbf{P}_l\mathbf{R} + \mathbf{T} \tag{2.2}$$

The y coordinates (height information) of the feature point do not require transformation assuming the vehicle stays horizontal to the plane of the road.

3 Results

The mobile unit was guided under remote control along a predefined path. The frame grabber (SNAPPER 24 bit) captured simultaneously the stereo pairs and overhead frames. This was achieved by connecting each camera to the separate red, green and blue channels of the frame video capture card. A common synchronization pulse was provided by a fourth camera. The resulting image sequence was processed to provide position and orientation data of the mobile unit for each stereo pair, (see Figure 3).

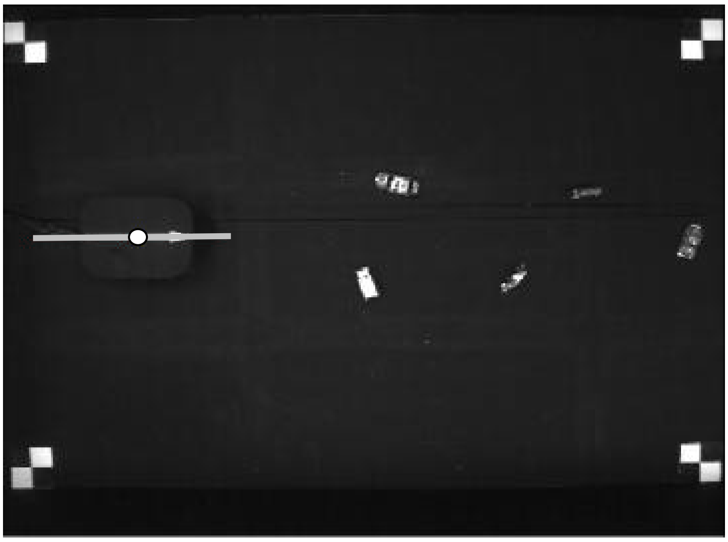
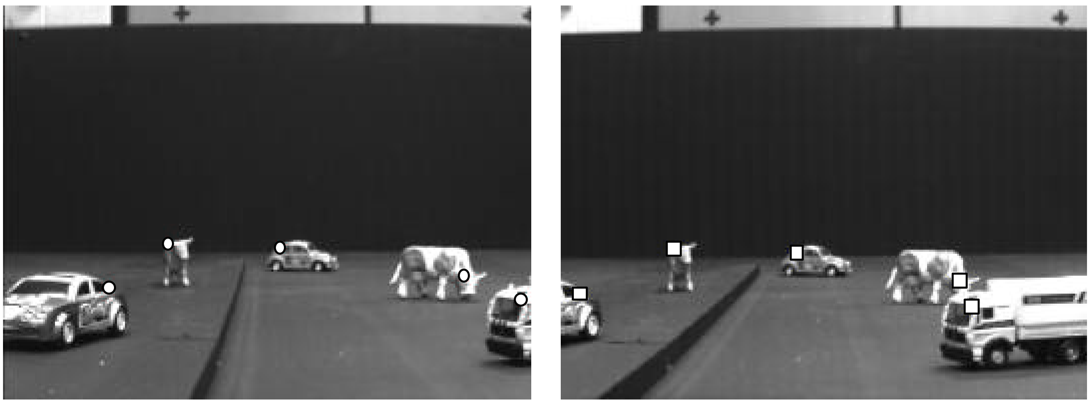


Figure 3 Overhead view of the scene.
Position and orientation of the mobile unit have been superimposed.

Feature points were identified in the stereo pair and the local coordinate evaluated (see Figure 4).



Left Image Right

Figure 4 Feature points identified in left and right images of the stereo pair

These data sets were then fused to produce global coordinates of the feature points. The feature points were then superimposed on an aerial view to provide a visual demonstration that the system was working (see Figure 5).

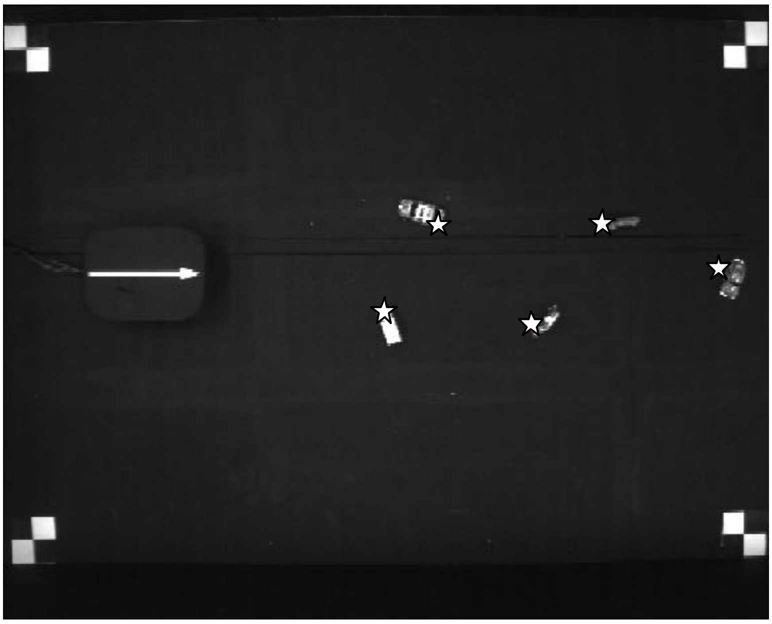


Figure 5 Overhead view of the scene.
Fused co-ordinates of feature points have been over plotted using stars.

4 Conclusion

The aim of this paper was to describe a method for fusing data provided by a mobile vision system with a GPS receiver. The results clearly demonstrate that such a system is realizable. The work is part of a larger project aimed at designing a system for automated inspection for infrastructure management. The software developed will form part of a full-scale system currently being developed. This system currently consists of a GPS receiver (Garmin 3+) and mobile stereo acquisition system with a 1.2m baseline. A further extension to this work will be to use the global position to assist in feature point tracking between frames.

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