## Surround-view camera system(VPM) online calibration

Cross-reference to related applications

This application claims the benefit of the priority date of U.S. Provisional patent application Ser. No. 61/994,649,titled, Surround-View Camera System(VPM) Online Calibration, filed May 16,2014.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates generally to a system and method for calibrating the cameras in a surround-view camera system on a vehicle and, more particularly, to a system and method for providing online calibration of the cameras in a surround-view camera system on a vehicle.

Discussion of the related art

Modern vehicles generally include one or more cameras that provide back-up assistance, take images of the vehicle driver to determine driver drowsiness or attentiveness, provide images of the road as the vehicle is traveling for collision avoidance purposes, provide structure recognition, such as roadway signs, etc. Other vehicle vision applications include vehicle lane sensing systems to sense the vehicle travel lane and drive the vehicle in the lane-center. Many of these known lane sensing systems detect lane-markers on the road for various applications, such as lane departure warning (LDW), lane keeping (LK), lane centering (LC),etc., and have typically employed a single camera, either at the front or rear of the vehicle, to provide the images that are used to detect the lane-markers.

It has been proposed in the art to provide a surround-view camera system on a vehicle that includes a front camera, a rear camera and left and right side cameras, where the camera system generates a top-down view of the vehicle and surrounding areas using the images from the cameras, and where the images overlap each other at the corners of the vehicle. The top-down view can be displayed for the vehicle driver to see what is surrounding the vehicle for back-up, parking, etc. Future vehicles may not employ rearview mirrors, but many instead include digital images provided by the surround view cameras.

U.S. Patent application Publication No. 2013/0293717 to Zhang et al., filed Apr.9, 2013, titled, Full Speed Lane Sensing With A Surrounding View System, assigned to the assignee of this application and herein incorporated by reference, discloses a system and method for providing lane sensing on a vehicle by detecting roadway lane-markers, where the system employs a surround-view camera system providing a top-down view image around the vehicle. The method includes detecting left-side and right-side lane boundary lines in the top-down view image, and then determining whether the lane boundary lines in the image are aligned from one image frame to a next image frame and are aligned from image to image in the top-down view image.

For many camera-based vehicle application it is critical to accurately calibrate the position and orientation of the camera with respect to the vehicle. Camera calibration generally refers to estimating a number of camera parameters including both intrinsic and extrinsic parameters, where the intrinsic parameters include focal length, optical center, radial distortion parameters, etc., and the extrinsic parameters include camera location, camera orientation, etc., camera extrinsic parameters calibration typically involves determining a set of parameters that relate camera image coordinates to vehicle coordinates and vice versa. Some camera parameters, such as camera focal length, optical center, etc., are stable, while other parameters, such as camera orientation and position, are not. For example, the height of the camera depends on the load of the vehicle, which will change from time to time.

In the known surround-view system, the images from the cameras overlap at the corners of the vehicle, where the camera calibration process “stitches” the adjacent images together so that common elements in the separate images directly overlap with each other to provide the desired top-down view. During manufacture of the vehicle, these camera images are stitched together to provide this image using any of a number of calibration techniques so that when the vehicle is first put into service, the cameras are properly calibrated. One calibration technique employed is to position the vehicle on a checker-board pattern of alternating light and dark squares where each point of the squares is suitably identified. Using these points in the developed images allows the camera calibration software to correct the position of the images so that overlapping points in adjacent images are identified at the same location.

However, once the vehicle is put into service various things may occur that could cause the orientation and position of the cameras to change, where the calibration of the camera includes errors causing misalignment in the top-down image. These things may include loading of the vehicle that causes camera position, such as height, and/or camera orientation, such as pitch, to change relative to world coordinates, small impacts to the vehicle which may change the position and orientation of the cameras, etc. However, current video processing modules (VPM) that process the images from the cameras to generate the top-down view are unable to recalibrate the cameras online while the vehicle is in use. Contrary, the vehicle operator must take the vehicle to a dealer or other authorized service center that has the ability to recalibrate the cameras in the same manner as was done during vehicle manufacture, which has obvious draw-backs.

SUMMARY OF THE INVENTION

The present disclosure describes a system and method for providing online calibration of a plurality of cameras in a surround-view camera system on a vehicle. Thee method provides consecutive images from each of the cameras in the surround-view system and identifies overlap image areas for adjacent cameras. The method identifies overlap image areas for adjacent cameras. The method identifies matching feature points in the overlap areas of the images and estimates camera parameters in world coordinates for each of the cameras. The method then estimates a vehicle pose of the vehicle in world coordinates using the estimated camera parameters in the world coordinates and the estimated vehicle pose to provide the calibration.

Additional features of the present invention will become apparent from the following description and appended claims, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is an illustration of a vehicle including a surround-view camera system having multiple cameras;

FIG.2 is an isometric view of a vehicle showing a coordinate system for world coordinates, vehicle coordinates and camera coordinates;

FIG.3 is a flow chart diagram showing a process for providing online surround-view camera calibration;

FIG.4 is a representation of four raw images from four cameras for the surround-view camera system showing matched feature pairs;

FIG.5 is a block diagram of a system showing a process for matching feature points;

FIG.6 is an illustration of a vehicle on a roadway and showing a process for determining vehicle pose; and

FIG.7 is a flow chart diagram showing a process for calibration validation and refinement.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The following discussion of the embodiments of the invention directed to a system and method for providing online calibration of cameras in a surround-view camera system on a vehicle is merely exemplary in nature, and is in no way intended to limit the invention or its applications or uses. For example, as discussed, the system and method has particular application for providing online calibration of cameras on a vehicle. However, as will be appreciated by those skilled in the art, the system and method may have application for other mobile platforms, such as on trains, machines, tractors, boats, recreation vehicles, etc.

FIG.1 is a top illustration of a vehicle 10 including a surround-view camera system having a front-view camera 12, a rear-view camera 14, a left-side driver view camera 16 and a right-side passenger view camera 18. The cameras 12-18 can be any camera suitable for the purposes described herein, many of which are known in the automotive art, that are capable of receiving light, or other radiation, and converting the light energy to electrical signals in a pixel format using, for example, charged coupled devices (CCD). The cameras 12-18 generate frames of image data at a certain data frame rate that can be stored for subsequent image processing in a video processing module (VPM) 20. The cameras 12-18 can be mounted within or on any suitable structure that is part of the vehicle 10, such as bumpers, facie, grill, side-view mirrors, door panels, etc., as would be well understood and appreciated by those skilled in the art. In one non-limiting embodiment, the side cameras 16 and 18 are mounted under the side view mirrors and are pointed downwards.

The cameras 12-18 generate images of certain limited areas around the vehicle 10 that partially overlap. Particularly, area 24 is the image area for the camera 12, area 26 is the image area for the camera 14, area 28 is the image area for the camera 16, and area 30 is the image area for the camera 18, where area 32 is an overlap area of the images 24 and 28, area 34 is an overlap area of the images 24 and 30, area 36 is an overlap area of the images 28 and 26, and area 38 is an overlap area of the images 30 and 26. Image data from the cameras 12-18 is sent to the VPM 20 that process the image data to stitch the images together that can then be displayed on a vehicle display as a single top-down view image around the vehicle 10.

As will be discussed in detail below, the present invention proposes an online calibration technique for calibrating the cameras 12-18 while the vehicle 10 is being operated. Software algorithms are known that employ rotation matrices R and transition vectors t to orient and reconfigure the images from adjacent cameras so that the images properly overlap. Generally, the proposed calibration technique defines three coordinate system, namely, a world coordinate system, a vehicle coordinate system and a camera coordinate system each defined in an XYZ positional orientation. FIG 2 is an illustration of a vehicle 50 including a camera 52 showing these coordinates system, where the subscript V represents the vehicle coordinates, the subscript W represents the world coordinates and the subscript C represents the camera coordinates, and where I represents the particular camera of the four cameras in the surround-view system.

As will discussed, the calibration technique finds matching feature points (u, v) in the overlap area 32,34,36 and 38 for two camera images, and based on the matching feature points (u, v) uses a transformation process to estimate camera parameters in world coordinates, and from there camera parameters in vehicle coordinates. Each feature point (u, v) is a representation of a particular pixel location in one image from a particular camera for a point X in an overlap region in the particular coordinate system. The calibration algorithm then provides feedback validation and tracking refinement.

For a particular point X in the overlap region the algorithm identifies a relationship between that points in the world coordinate system to the vehicle coordinate system,