Automated Real-Time Dimension Measurement of Moving Vehicles Using Laser Rangefinders

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ABSTRACT

Range sensing and range image based geometric modeling is a promising new technique that found many industrial applications. In this work, we applied this technique to the real-time dimension measurement of moving vehicles on highways. The study was a continuation of our research on range image based geometric modeling for intelligent robotic and manufacturing applications. The project was carried out with the supports and collaborations from the users of the technology – highway and ferry authorities, and the manufacturer of the range-finding scanners. In this paper, an overview on the two most commonly used range sensing techniques and range image based geometric model generation are briefly reviewed. The specifications of the Automated Vehicle Dimension Measurement System (AVDMS), the developed range-finding scanners, and the key issues on range data acquisition and vehicle dimension measurement are then discussed. Results of the AVDMS prototype testing are provided to demonstrate the capability of the system. The technology has a great potential to be used in many similar industrial applications.

KEYWORDS: laser range sensing, dimension measurement, range image based geometric modeling.

INTRODUCTION

With many processes in industry becoming automated, it is often important to make spatial observations of various objects, machinery and the working environment, and to make remote measurements in applications with rugged environments or where manual measurements are not efficient or permissible. These observations are normally made using range sensing devices. These devices commonly use laser light as the measurement medium since light wave can easily be focused, and it travels quickly to and from the objects and environment. The vision system of many developed intelligent robotic and manufacturing systems are based upon this technique.

Today's competitive industrial environment and global economy demand more efficient traffic control, commercial fleet monitoring systems, and automated tolling systems. In British Columbia, the B.C. Ferry Corporation has a number of ferry routes

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that connect the mainland to Vancouver Island. Between Tsawwassen and Schwartz Bay alone, more than 10,000 commercial and oversize vehicles use the B.C. Ferries each month. This large number of vehicles requires efficient management to maintain ferry schedules while transporting the maximum number of vehicles per trip. Currently, fares for commercial and oversize vehicles are determined based on vehicle length. The existing system requires toll booth staff to manually measure the length of each vehicle. This is an inefficient and labor-intensive method that does not account for the variation in height and width of different vehicles. In order to improve the efficiency, accuracy, and comprehensiveness of determining and collecting fares for commercial and oversize vehicles, it was decided that toll collection should be based on the volume of oversize vehicles and that a system was required to automatically measure vehicle dimensions. Range sensing and range image based geometric modeling is an idea technique for this application.

Range sensors and range sensing technology have gained considerable attention in recent years. Due to its superior capability to provide an accurate and informative 3D range profile of the scanned objects and environment, range sensing becomes an emerging technology for many design and manufacturing applications. Some examples of applications where range sensors are being used include: geometric model generation [1,2], reverse engineering [3], manufacturing accuracy control [4], finishing, inspection and quality control [5], robotic applications [6,7], surface topography measurements [8], basic measuring systems in 1-D, 2-D, or 3-D [9], and autonomous vehicles [4]. Most of these applications used laser light. With recent development in the ability to focus sound waves, they too are being used in range sensing, depending on the application.

The technical requirements of the Automated Vehicle Dimension Measurement System (AVDMS) is to measure the dimensions of commercial vehicles traveling at speeds up to 120 km/hour with a measurement accuracy of 15 cm in height and width, and 30 cm in length. The measurements and calculations must be made in real-time as each vehicle passes through the system helping reduce queue sizes at the toll booths and improving efficiency. This information is used to calculate the volume of each vehicle for determining the fare for the vehicle.

RANGE SENSING DEVICES

Most commonly-used range sensing devices can be classified into two categories. These are the triangulation based devices and time-of-flight (TOF) based devices. Triangulation devices are used at shorter ranges where high accuracy is required. For example, many mechanical part profile scanning devices use triangulation based laser range sensors for quality control and reverse engineering applications where high precision is required. TOF laser range-finding technology has been developed more recently and is typically used at ranges not less than a few meters. These TOF systems have a range measurement accuracy from a few millimeters to a few inches depending mainly on the rate of measurement. It is common for both triangulation and TOF sensors to use rotating mirrors to facilitate high speed scanning of an object and its environment. Both of these optical sensing techniques can be used to acquire 3D range data. After obtaining 3D range images from a particular scene, a geometric model of the object(s) and the environment is generated to geometrically define the objects and environment as required for a given application. Views of an object from multiple locations to obtain the complete geometric model of the object are often necessary. This leads the need to perform multiple-view fusion from separately acquired range images [1,2].

Considering the problem of measuring the dimensions of vehicles traveling along the highway, a system is required that can make size measurements in quick succession from a distance. Several technologies were considered, including image processing with 1-D and 2-D gray image cameras (a linescan camera curtain, stereo pair linescan cameras, or a CCD camera), light curtain techniques with photo-electric sensors (transmitted beam sensors, retro-reflective sensors and proximity sensors), and 2D range imaging with laser range-finding scanners. After investigating the most promising range sensing techniques for the dimension measurement of vehicles, the most suitable method and the only proven technology considered suitable for the AVDMS was laser range-finding scanners. Processing speed and development time constraints are also part of the consideration.

OVERVIEW OF THE AVDMS SYSTEM

The AVDMS system consists of two high-speed infrared laser range-finding scanners and an infrared laser vehicle speed sensor, connected to a 66 MHz/80486 personal computer. The architecture of the prototype system is illustrated in Figure 1.

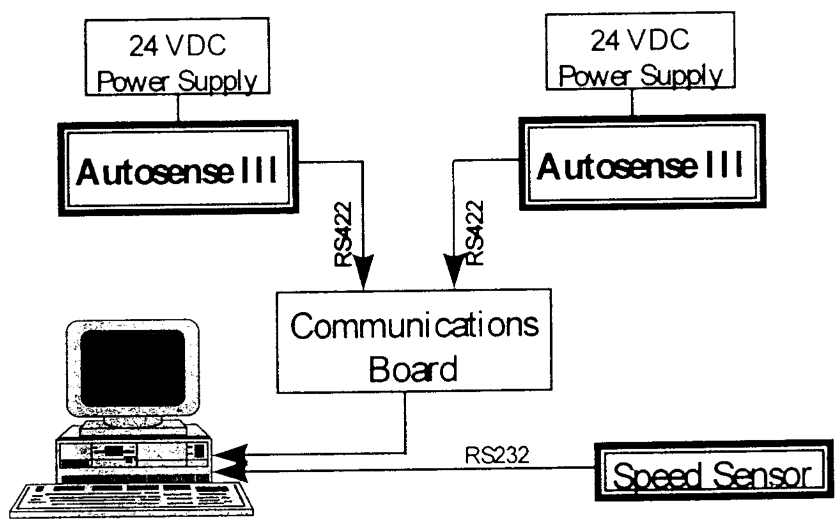

Figure 1 Hardware of the AVDMS

The AVDMS system operation flowchart, indicating the method in which vehicles are processed, is shown in Figure 2. Specifications for the laser scanners and speed sensor were developed based upon the targeted function of the AVDMS. These specifications were provided to Schwartz Electro-Optics (SEO), the manufacturer of the range-finding scanners and speed sensor.

The vehicles are scanned from both sides to cover the entire length. The location of each scanner is known and the range measurements, relative to the scanners, define the perimeter of the vehicles as they pass through the scan gate. Each scan is processed immediately recording the highest and widest point on the vehicle for that scan. After the

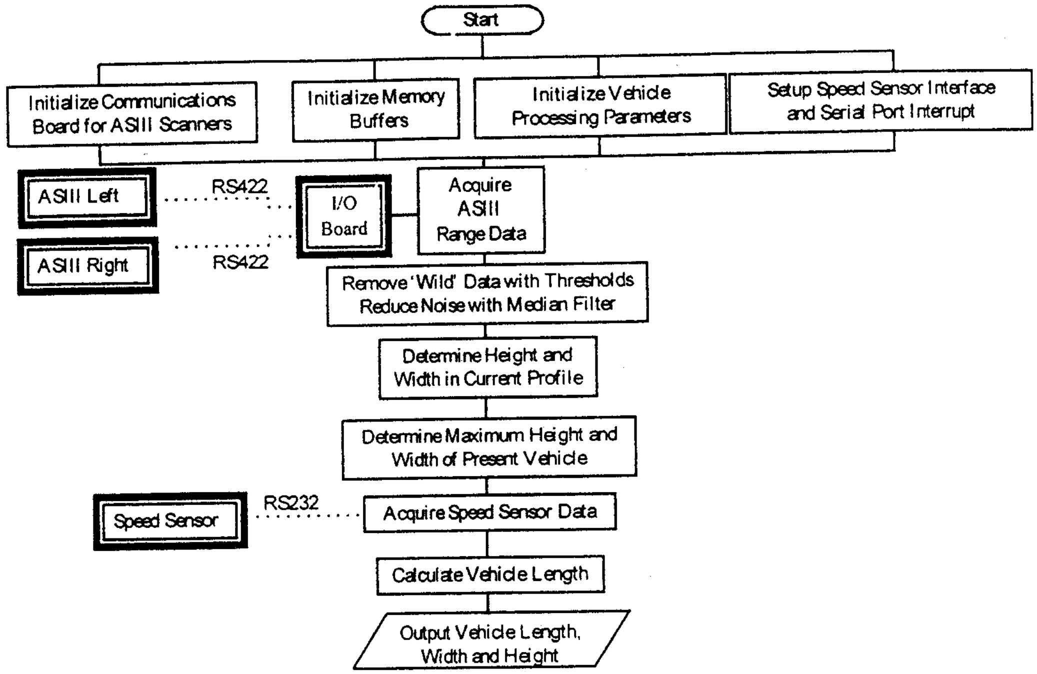

Figure 2 Functional Modules of the AVDMS

entire vehicle has passed through the scan gate, the maximum height and width of the vehicle are obtained. Each scan produces an array of 118 range values which correspond to polar coordinate measurements made at equal angular intervals. These range values are transformed to height and width values using a simple geometric transformation of the values from the polar coordinate system to the Cartesian coordinate system. Since the measurement angles are known and constant for each scan, an array of fixed constants can be used to translate the array of range values to height and width values. The array of constants are simply sine and cosine values calculated at 0.5 degree intervals over a 59 degree field of view as shown in Figure 3. The acquired range image data are processed upon arrival to the computer. First of all, maximum and minimum threshold values are set to eliminate any extreme values or wild data. Secondly, a three-point median-type filtering process is used on each scan. This filter uses a window with a size of three data values to look through the linear array of range values starting from the second value and ending with the second to last value. This three-point median filter works effectively on the vehicle data by replacing the odd "bad" range value with a neighboring range value without significantly altering the "good" range values. To determine the length of the vehicle, a speed sensor is incorporated into the system. A SEO laser range/speed sensor with the a speed measurement accuracy of 0.55 km/hour (0.34 mile/hour) was adopted to achieve expected vehicle length measurement accuracy. Dedicated software was developed to access the 16 bit times in the PC that ticks at 1.19 MHz, and to incorporate the speed reading into the vehicle length calculation.

The AVDMS prototype system went through extensive laboratory and road tests, as shown in Figure 3. An example commercial vehicle and its range image, produced by the AVDMS prototype, is shown in Figure 4.

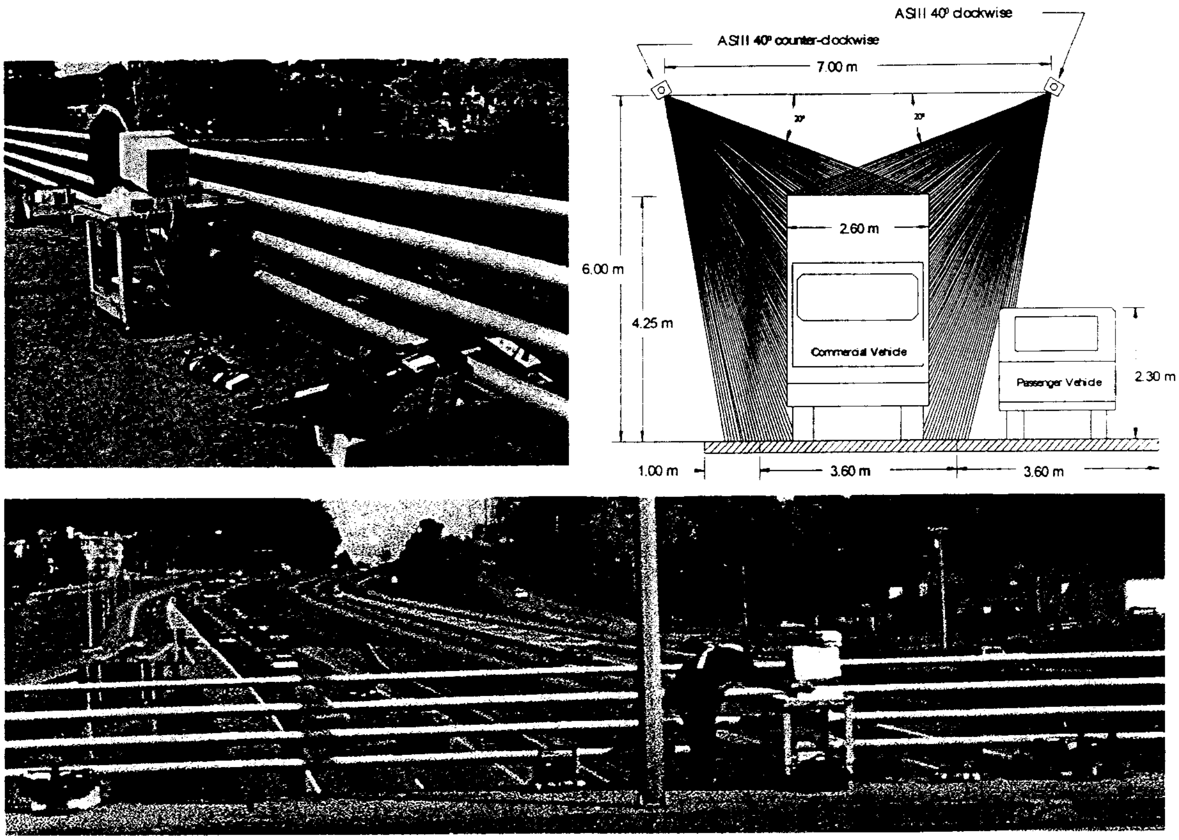

Figure 3 AVDMS Working Principle and Road Test of the Prototype

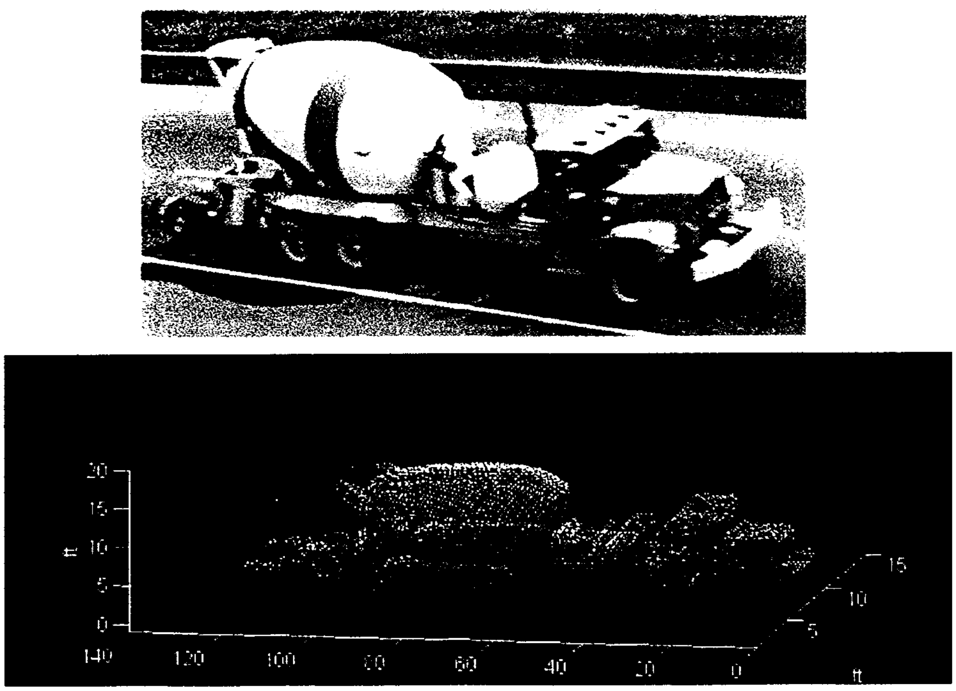

Figure 4 Range Image Obtained Using the AVDMS Prototype

SUMMARY

The real-time automatic vehicle dimension measuring system (AVDMS) developed in this work is the first system capable of automatically measuring the dimensions of vehicles traveling at highway speeds. The AVDMS has demonstrated the capability and usefulness of the technology in a high-speed scanning application to acquire three dimensional range data. Due to the superb quality of the range images acquired by the rangefinders, the technology has a great potential to serve as the data acquisition tool for the development of an automated vehicle recognition and classification system. The research also contributes to the better understanding of range-finding devices and their capabilities. The developed technology can be applied to many of the applications where fast-moving objects have to be scanned under hostile outdoor environments.

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