An Infrastructure for the Next-Generation Highway Data Vehicle

Final Report

Mack-Blackwell Transportation Center

Principle Investigator:

Kelvin C.P. Wang

Civil Engineering
4190 Bell Engineering
University of Arkansas
Fayetteville, AR 72701

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Kelvin C.P. Wang

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16. Abstract

After a number of years' research on highway information systems, the research team at the Department of Civil Engineering, University of Arkansas, has made substantial progress in the development of a digital highway data vehicle and a Multimedia based Highway Information System (MMHIS). MMHIS is useful for pavement management, design improvement, accident analysis and traffic studies, transportation planning, and other highway engineering related tasks. Another major portion of the research is data collection of highway infrastructure systems. As existing data collection vehicles primarily use decades old analog technology, there is a need to develop a new data collection technique that is low-cost and high-performance on one hand, and is integrated with MMHIS on the other. This project focused on refining of the design of the new data vehicle and developing related technology to digitally acquire highway information. This project established an infrastructure for the digital vehicle, including the conversion of the base vehicle, installation of equipment, and prototyping development of integration technology. The digital data vehicle provides a platform for today's automated distress survey.

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ABSTRACT

After a number of years' research on highway information systems, the research team at the Department of Civil Engineering, University of Arkansas, has made substantial progress in the development of a digital highway data vehicle and a Multimedia based Highway Information System (MMHIS). MMHIS is useful for pavement management, design improvement, accident analysis and traffic studies, transportation planning, and other highway engineering related tasks. Another major portion of the research is data collection of highway infrastructure systems. As existing data collection vehicles primarily use decades old analog technology, there is a need to develop a new data collection technique that is low-cost and high-performance on one hand, and is integrated with MMHIS on the other. This project focused on refining of the design of the new data vehicle and developing related technology to digitally acquire highway information. This project established an infrastructure for the digital vehicle, including the conversion of the base vehicle, installation of equipment, and prototyping development of integration technology. The digital data vehicle provides a platform for today's automated distress survey.

PROJECT DESCRIPTION

System Design for A Next-generation Data Vehicle

Image collection of both front-view and pavement surface is the first step in analyzing the visuals either manually or using machine vision. The major factor of concern is the cost-effectiveness of new technology in system implementation. Based on currently available technology, the following are the characteristics of the digital data vehicle:

(1) Real-time data collection of roughness, rutting, front-view image, pavement surface image, and data processing and analysis

(2) The resolution and quality of all images exceeds those of current data vehicles

(3) Use of off-the-shelf components and devices for the construction of the vehicle

(4) Full digital imaging devices for data collection of both front-view and pavement surface

(5) Use of microcomputers and computer storage arrays to archive image and all other data without using analog tapes or laser disks

(6) Use of microcomputer based parallel processors to analyze data at real-time in the vehicle

Figure 1 illustrates the system design of the digital data vehicle. The data vehicle system consists of four sub-systems. The first is the pavement surface imaging with one high-frequency line-scan camera. The second is the dual digital camera vision system for front-view images. The third is the microcomputers, storage arrays and imaging boards. The fourth consists of the devices used to measure pavement roughness and rutting. The technology for the fourth sub-system is mature and its components are widely available. Because of this , the paper concentrates on first three sub-systems which utilize fundamentally different technologies from current practices. However, the data vehicle based on the new design is expected to solve many performance-related problems at a cost that is comparable to current systems. The new system also includes peripherals, such as a Global Position System (GPS) receiver, speed encoder, and an external sync source for the line-scan camera. The GPS receiver will be used to identify spatial coordinates of the data vehicle.

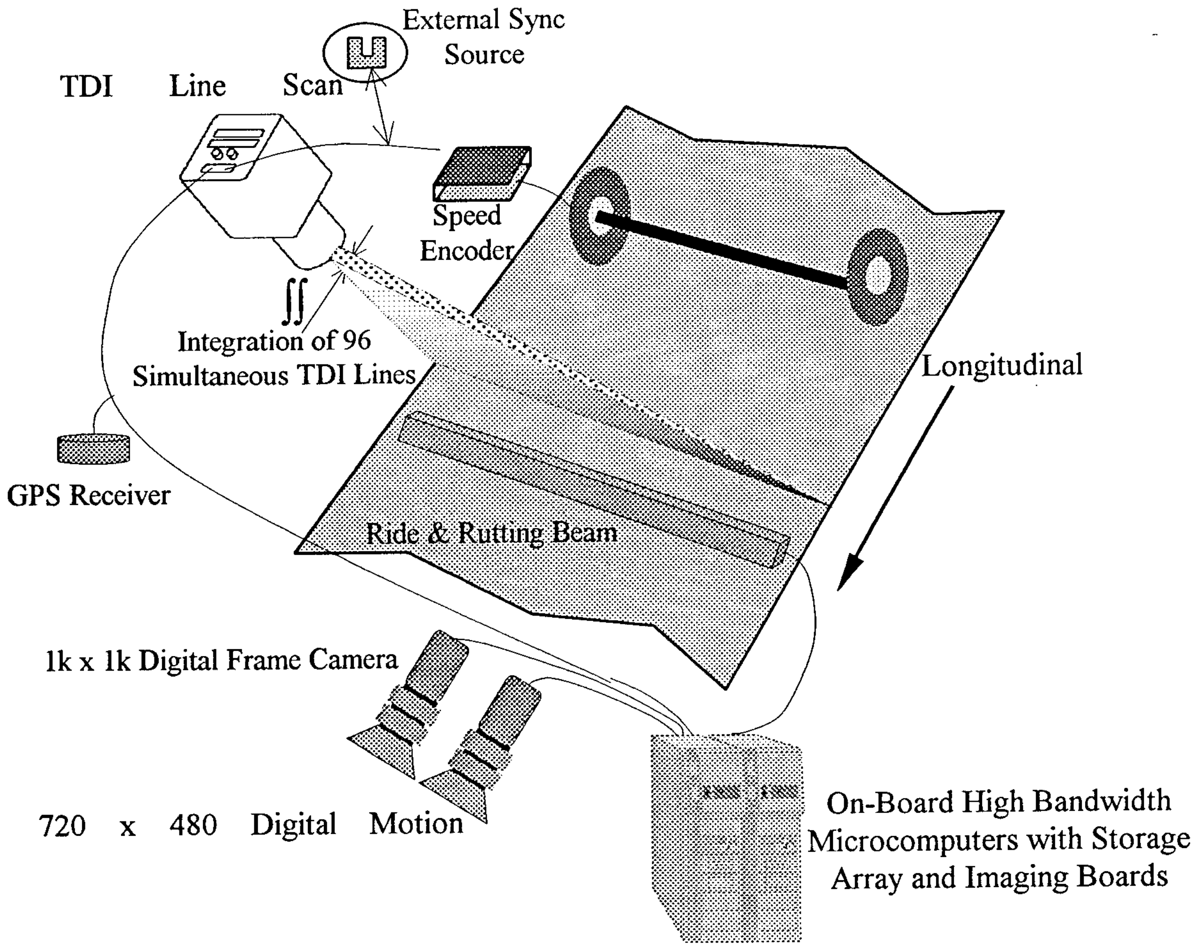


FIG. 1 Elements in the Digital Data Vehicle

Data Storage and Image Processing

There are a number of technical difficulties in implementing a true automated distress survey system. The overwhelming difficulty is the high data rate and associated extraordinary computation needs when real-time or near real-time processing is necessary. Under the following assumptions:

(1) 8-bit gray scale images

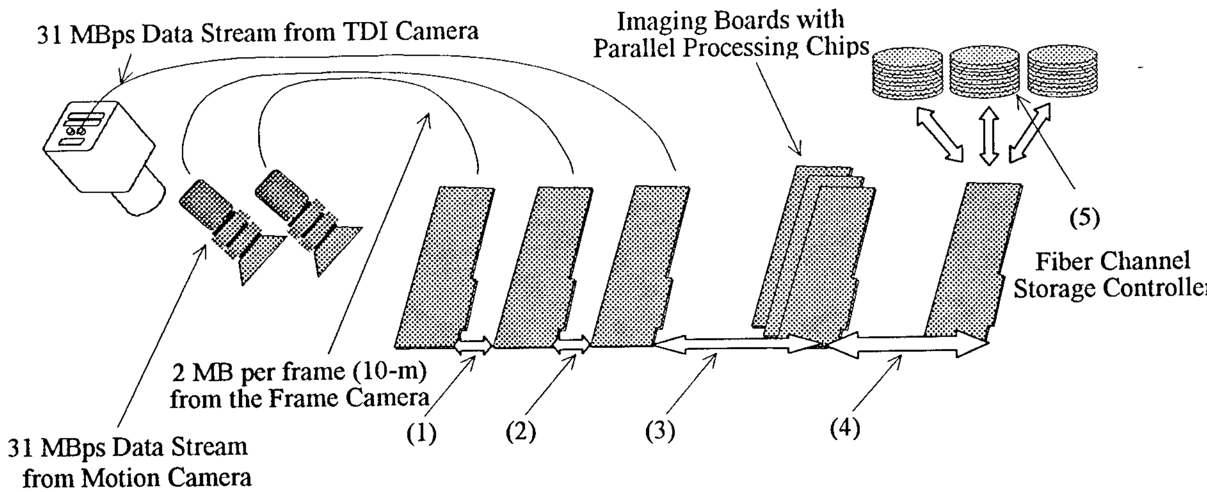
(2) 12-foot pavement width

(3) 2048 pixels per-line-per-lane

(4) uniform resolution in both direction on the 2-D surface

(5) vehicle speed of 100 km/h

The resulting in-coming raw data rate from the camera is about 3.1 megabytes per second (MBps) after 10:1 compression. Figure 2 illustrates the data flow and storage needs in the digital data vehicle.



(1) 0.2 MB per frame (10-meter) after compression by the JPEG Board via the PCI Bus
(2) 3.1 MBps stream after compression by the MPEG-2 CODEC Board via the PCI Bus
(3) 3.1 MBps stream after compression by the JPEG Board via the PCI bus
(4) System data pipe of combined data streams about 7.5 MBps, including real-time data from GPS, ride and rutting bar and other peripherals (assume the speed of 100 km/h)
(5) Data streams are archived through the Fiber Channel storage controller to an on-board Disk Array system

FIG. 2 Flow of Data Streams within the Vehicle

The data streams into the system disk array have a rate between 7 to 8 MBps after compression at the speed of 100 km/h, resulting in storage of 252 to 288 Gigabytes for a 1,000-km survey trip. The storage controller will be based on the new Fiber Channel technology with 100 MBps data rate. After each surveying trip, the entire database in the disk array can be downloaded into the data server at the highway agency through the 100 MBps pipe in less than one hour.

Cost-Effectiveness of the Next-generation Vehicle

The digital data vehicle is based on current available devices from commercial sources. Therefore, no customization will be needed, except for the modification of the vehicle to accommodate equipment. Existing data vehicles with capabilities of measuring ride, rutting, and conducting certain aspect of surface distress survey cost nearly one million dollars per vehicle. Based on the cost analysis, the cost of the next-generation data vehicle will be similar to or less than that of an existing data vehicle. In addition, the new features and new capabilities of the next-generation vehicle will make data collection easier, provide a much more convenient path to deliver the collected data, and improve the overall decision-making process in a highway department.

Figure 3 illustrates the exterior of the digital highway data vehicle. Figure 4 shows the interior of the vehicle.

FIG. 3 Exterior View of the Completed Digital Data Vehicle

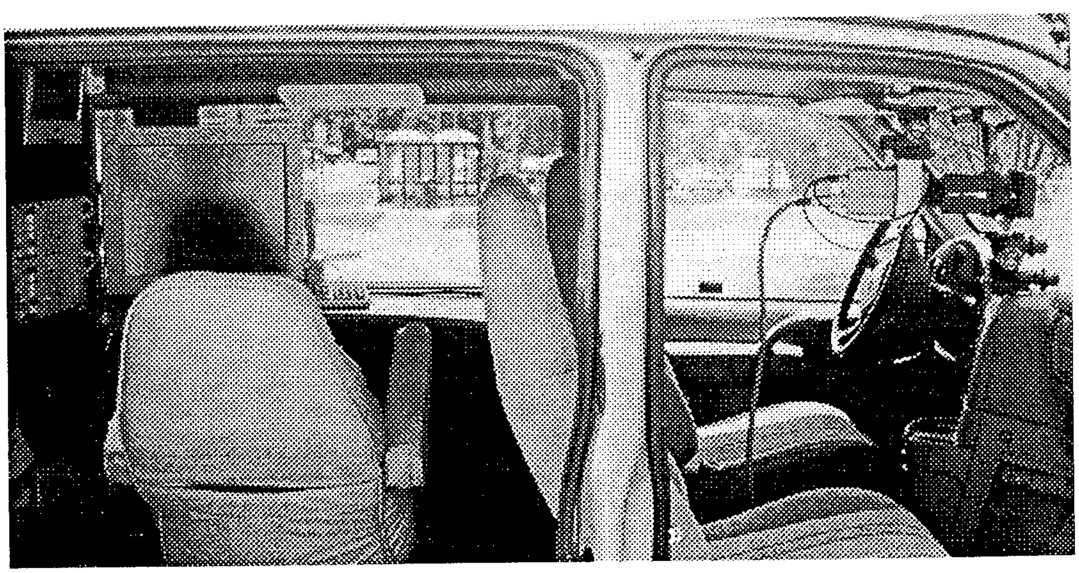


FIG 4. Interior View of the Digital Data Vehicle

AUTOMATED DISTRESS SURVEY AND MULTIMEDIA BASED HIGHWAY INFORMATION SYSTEM, MMHIS

Even though it is not an immediate objective of the project, automated distress survey has always been a primarily goal to develop the digital highway data vehicle. FIG. 5 illustrates the real-time processing interface of the automated distress analyzer.

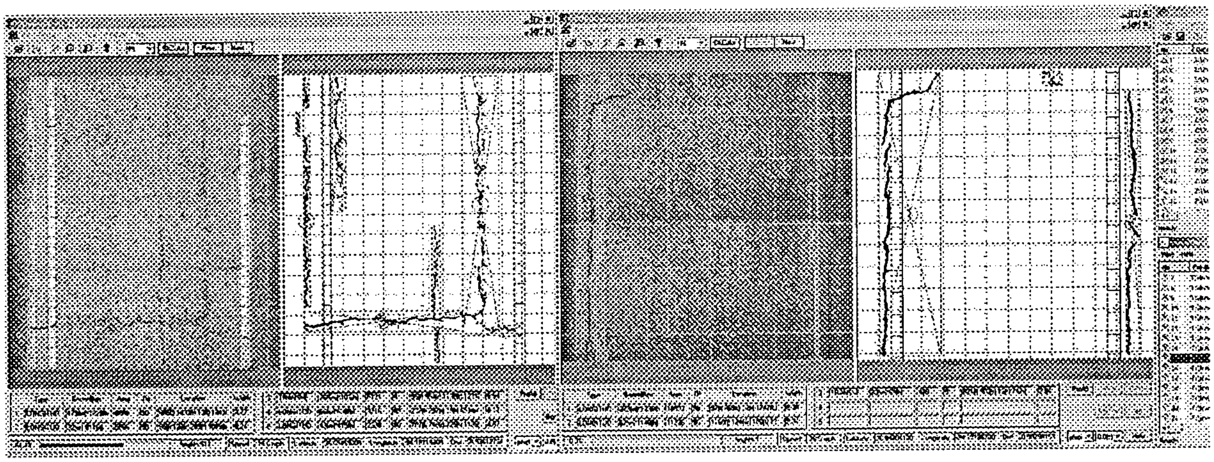


FIG. 5 Automated Distress Analyzer with Parallel Processing

Along with the development of the digital data vehicle, the Multimedia based Highway Information Systems, MMHIS, has been in development for the Arkansas highway department. MMHIS and the digital data vehicle become an integrated system for information access for a highway agency.

CONCLUSION

A large part of the current project was to support the remodeling of the base vehicle and installation of various hardware components. In particular, the result of the project provides hardware and software platforms for automated distress survey and other data collection of visual information. It was fortunate that the support from MBTC through this project produced a world first real-time distress analyzer for pavements and made our research and the university well known.