NETWORKED DATA ACQUISITION DEVICES AS APPLIED TO AUTOMOTIVE TESTING

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ABSTRACT

The US Army Aberdeen Test Center (ATC) is acquiring, transferring, and databasing data during all phases of automotive testing using networked data acquisition devices. The devices are small ruggedized computer-based systems programmed with specific data acquisition tasks and then networked together with other devices in order to share information within a test item or vehicle. One of the devices is also networked to a ground-station for monitor, control and data transfer of any of the devices on the net. Application of these devices has varied from single vehicle tests in a single geographical location up to a 100-vehicle nationwide test. Each device has a primary task such as acquiring data from vehicular data busses (MIL-STD-1553, SAE J1708 bus, SAE J1939 bus, RS-422 serial bus, etc.), GPS (time and position), analog sensors and video with audio. Each device has programmable options, maintained in a configuration file, that define the specific recording methods, real-time algorithms to be performed, data rates, and triggering parameters. The programmability of the system and bi-directional communications allow the configuration file to be modified remotely after the system is fielded. The primary data storage media of each device is on-board solid-state flash disk; therefore, a continuous communication link is not critical to data gathering.

Data are gathered, quality checked and loaded into a database for analysis. The configuration file, as an integral part of the database, ensures configuration identity and management. A web based graphical user interface provides preprogrammed query options for viewing, summarizing, graphing, and consolidating data. The database can also be queried for more detailed analyses. The architecture for this network approach to field data acquisition was under the Aberdeen Test Center program Versatile Information System Integrated On-Line (VISION). This paper will describe how the merging of data acquisition systems to network communications and information management tools provides a powerful resource for system engineers, analysts, evaluators and acquisition personnel.

KEYWORDS

Networked Data Acquisition, Automotive Testing, Safety Systems, and Nationwide.

BACKGROUND

The methods associated with acquiring, transferring, consolidating and analyzing automotive data for long-term tests have evolved as electronic technology has evolved. In the late 1970's, one method of data acquisition during automotive tests was a cassette tape recorder that recorded continuously for a fixed period of time. The cassette was then removed from the recorder, inserted into a reader, played back to a computer, and then the data were printed for review and analysis. In the mid-1980's, the introduction of solid state memory and microprocessors allowed for more intelligent data acquisition systems. Data could be recorded at variable rates, different formats, and when triggered by out of limit conditions. Data were commonly transferred by serial data links, processed to reformat it for viewing, and then formatted for import to a database.

SYSYTEM DESCRIPTION

Aberdeen Test Center's Versatile Information Systems Integrated ON-line (VISION) initiative integrates data acquisition with information systems technology. VISION encompasses data acquisition, data communication, data archiving, and data presentation. The data acquisition portion of VISION is called the Advanced Distributed Modular Acquisition System (ADMAS). ADMAS is a suite of network data acquisition devices that are configured for the required application. All ADMAS devices are industrial embedded computer systems with common operating system, solid-state storage, and the communications interfaces. Each device operates with a Commercial off the Shelf (COTS) operating system and ATC developed application software that works with a configuration file to make the system very flexible. The programmable configuration file controls the operation of each device. The configuration file is the keystone for the VISION system because its content controls the networking, data acquisition, real-time data views, real-time data processes, data communication and loading of the data to the database.

Individual ADMAS devices have the specific interface circuits for analog sensor inputs, digital inputs and serial data busses. The Global Positioning System (GPS) Device is the centerpiece of the typical ADMAS application because it acts as an Ethernet gateway, time synchronizer and metadata input device. The device interfaces to a GPS receiver, records the time and position information and broadcasts the time to other devices on the network. The other devices on the network may be the Analog Device, Mil-Std-1553 Device, the SAE J1708 and SAE J1939 Device, and the Video Device. Each device is programmed individually or may be programmed over the network. Data are recorded on each device in the solid-state removable flash memory. The amount of memory required for each device can be tailored to the application because there is a wide selection of storage capacity in COTS memory cards. Each device is also a web server thereby allowing data viewing and control software to be a generic web program such as Internet Explorer. The real-time display from each device may then be viewed over the network.

The Analog Device is utilized for acquiring data from sensors. It has 16-bit 32-channel analog-to-digital capability with programmable sample rates up to 6000 samples-per-second. It can record data in different formats such as continuous time history or pre-trigger/post-trigger format. The configuration file can set the conditions for recording, the format and the pre-trigger and post-trigger duration. The Mil-Std-1553 Device records a dual-redundant data bus in several modes. It can be configured to record every message on the bus, to record only specific messages on the bus or to record the complete bus in a compressed format. The SAE J1708 and J1939 Devices record data from the automotive data busses on commercial and military trucks. The Video Device accepts NTSC video and can record continuously or on event. The event occurs based on the data from one of the other devices. When the event occurs on the other device, the Video Device will store in a pre-trigger/post-trigger format surrounding the event. This flexibility allows only video of interest to be recorded based on the data from the other devices. The VISION initiative has been implemented in during several military automotive tests but the implementation during the Intelligent Vehicle Initiative project is described in detail in this paper.

PROJECT DESCRIPTION

Through previous research, the National Highway Transportation Safety Administration (NHTSA) was able to develop initial estimates which show that rear-end, lane change, and roadway departure crash avoidance systems have the potential, collectively, to reduce motor vehicle crashes by one sixth, or about 1.1 million crashes annually. Such systems may take the form of warning drivers, recommending control actions, and introducing temporary or partial automated control of the vehicle in hazardous situations. U.S. DOT has harnessed these efforts into one program, the Intelligent Vehicle Initiative. Research has been focused on eight safety related areas: rear-end collisions, roadway departure collisions, lane change and merge collisions, intersection collisions, driver impairment monitoring, vision enhancement, vehicle stability, and safety impacting systems. The areas of research are also divided among light (cars), transit (city busses), specialty (snowplows) and commercial vehicles.

Commercial vehicles are heavy trucks and interstate busses. The problem areas for this type of vehicle are well defined and documented. Commercial vehicles will leverage the performance specifications being developed under the light vehicle program for rear-end, lane change/merge, roadway departure, and intersection collision avoidance. The commercial vehicle platform will lead the research in drowsy driver, rollover and stability-related crashes, intelligent diagnostics, and electronic braking. The Volvo Trucks North America (VTNA) portion of the research emphasizes the adaptive cruise control, rear-end collision warning, and implementation of electronic braking systems. Electronic braking systems are being fielded for the first time in the United States. The 2-year, 100 vehicle, nationwide operational test will allow DOT, VTNA, the evaluator, Battelle, and a commercial fleet, U.S. Xpress, to understand the required technical performance, user acceptance, and benefits of the collision countermeasures.

DATA ACQUISITION REQUIREMENTS

The IVI data acquisition requirements for the Field Operational Test were for an instrumentation system that would record data under specific conditions, transfer the data from anywhere in the continental U.S. and Canada, and provide a database for data viewing and reporting (fig.1). The standard ADMAS physical footprint was not practical in this application due to location restrictions. Therefore a modified ADMAS was fabricated that contained all the capabilities but in an applicable form factor.

The operational requirements for the Data Acquisition System (DAS) were to record one set of parameters in a histogram format, another set of parameters in the triggered time history format and a third set in a time-tagged event format. The histogram format is to provide the evaluator a statistical overview of the environment the vehicle experienced. The triggered time history format is one where if one or more of the monitored parameters exceeds a limit, a flag or trigger is generated. On the occurrence of the trigger, data pertaining to X number of samples prior to the trigger and Y number of samples after the trigger are recorded. This data versus time record will allow an analyst to ascertain what led up to a situation and how it was resolved. To better understand the data, video recordings were desired during the triggered time history. The time-tagged event format provides just a single sample of data from a set of parameters when an event has occurred. This provides a compressed method of recording all occurrences of an event and the conditions in which the event was generated.

The parameter sources are three vehicle data busses, three analog sensors and Global Positioning System (GPS) time and location. Each DAS unit had to be non-intrusive with data retrieval accomplished with minimal human contact. The test length of two years required that data acquisition be selective and concise; therefore it was desired that the DAS communicate status and data to a central facility in order to flag faulty units for replacement. The communication was also desired in order to allow modifications to the data acquisition plan to be implemented without stopping a truck. This was critical because the test trucks were in standard revenue generating operations and there was to be no interference with their activity. The communication coverage had to be nationwide because each truck is independent of a fixed schedule and route. Data received were to be databased and query and reporting tools were to be provided.

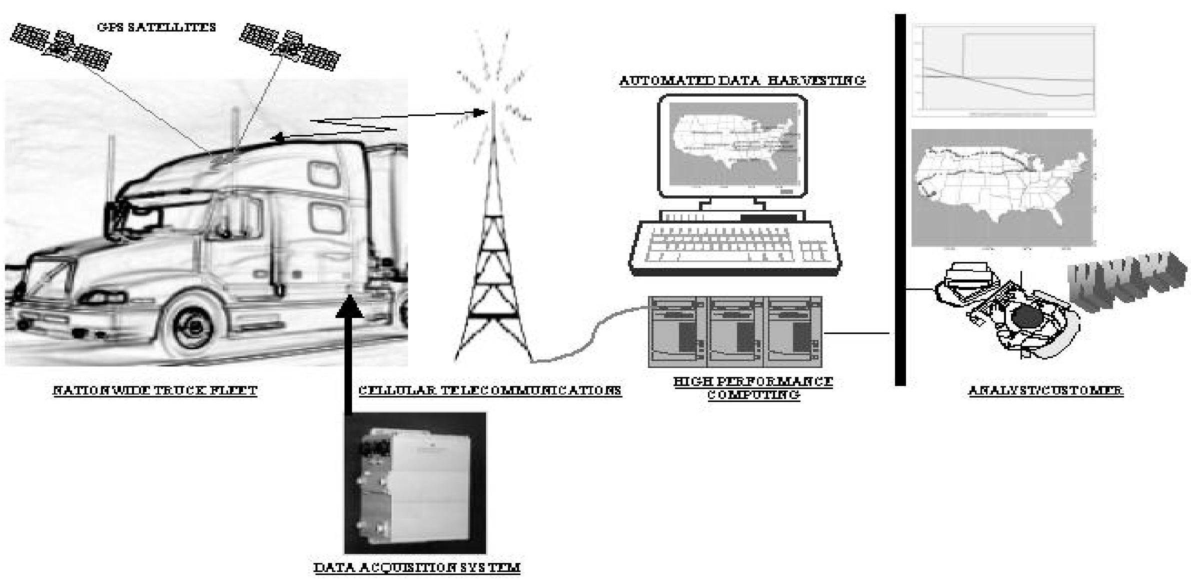

Fig. 1: IVI Instrumentation System

DATA ACQUISITION SOLUTION

The requirements matched the VISION initiative objectives. The DAS for the IVI project is a modification of an ADMAS device. An existing ADMAS device met many of the requirements but modifications were required in order to meet all the project's requirements. The modifications were the integration of a cellular modem for nationwide communication, a modified outer shell, an integrated bi-axial accelerometer, custom front panel connectors and a custom serial port to accept the Collision Warning System (CWS) data bus. Implementation of the Video Device was limited to six vehicles. The Video Device was networked to the DAS over Ethernet.

Fig. 2: IVI Data Acquisition System (DAS)

The DAS hardware consists of a single-board PC-104 form factor computer with additional PC-104 data acquisition and communications interface boards. The computer utilizes a real-time operating system and stores the operating system, application program, and configuration file in solid-state 32-Mbyte Disk-On-Chip (DOC) media. The system includes a removable PCMCIA 220-Mbyte flash memory card for data storage and an Uninterruptible Power Supply (UPS) in a rugged aluminum enclosure (Fig. 2.).

The DAS software works with a configuration file. The configuration file denotes which parameters to record, how and when to record the data, which real-time algorithms to perform and the limit or trigger conditions that will initiate data recording. The SAE J1708, SAE J1939 and CWS data buses contain many parameters. The configuration file has the appropriate fields to designate the specific data word, data byte or individual bit that requires monitoring and/or recording. Once a parameter has being selected, it can be recorded and used as a variable in real-time algorithms. Some parameters, such as road speed and following distance, are recorded continuously in the histogram format. Simultaneously, the following distance divided by road speed process is performed and the result is the following interval (in seconds). That parameter is also recorded in the histogram format. The following interval parameter is one of the trigger conditions, therefore its value is limit checked by another line in the configuration file. When the limit is exceeded, data is recorded in the triggered time history format.

From the SAE J1708 data bus, the Vehicle Identification Number (VIN) and vehicle fault codes are recorded. The DAS was programmed to request the VIN from the truck. This allowed any DAS to be installed on any vehicle without having to maintain a paper trail. The vehicle fault codes are recorded, as they occur, to record the vehicle health status. From the SAE J1939 data bus, nine parameters are parsed including road speed; brake pedal percentage, ABS active, and the odometer. The CWS data bus provided seven parameters including following distance, relative velocity and collision warnings indicators.

The DAS has 16 analog input channels but for IVI only 3 channels are used. The longitudinal and lateral accelerations are measured by accelerometers integrated to the DAS package. The third analog input is a string potentiometer situated to measure steering wheel position. All the analog inputs are sampled at 6 samples-per-second with a 16-bit analog-to-digital converter. Monitoring and recording the serial data from a GPS receiver provides the time and position data. This data is recorded at the beginning and end of each histogram file and the trigger time of each triggered time history file.

For the IVI project data are stored in three formats, histogram, triggered time history and time-tagged events. The histogram format stores nine data parameters at the rate of six samples per second. A histogram data file will begin from the time the DAS is turned on. The data file is closed after three hours if the vehicle is in operation, at which time a new histogram file is begun, or it is closed when the vehicle is turned off. With the triggered time history format, seventeen data parameters are monitored continuously at six samples per second in a circular data buffer. The circular data buffer is an area in memory that temporarily stores a specified amount of data. If one of eight designated limits is exceeded, then a trigger event is created. When the trigger event occurs, the previous ten seconds of data will be stored permanently along with the five seconds of data after the trigger event. In addition to the seventeen parameters, six additional values are stored at the trigger time such as GPS time, latitude, longitude and the trigger source. These values are considered metadata. The time-tagged event data file is opened at the same time the histogram file is created. One sample of data from seventeen parameters and time is stored in the time-tagged event file whenever the CWS emits an audio tone. This maintains a record of how many tones a driver hears and the snapshot of data that is associated with the tone.

After the individual histogram, triggered time history, or time-tagged event data files are closed, the DAS compresses the data file and copies the compressed file to a temporary directory on the solid-state flash drive. From this temporary directory the data files are transferred using the cellular modem. When the DAS detects that the vehicle has stopped for a least three minutes and the cellular signal is adequate, it will initiate a phone call to the data-harvesting servers at ATC. With the cellular modem connection established, the DAS will transfer the compressed data files in a last-in first-out order. All transferred files are cyclic redundancy checked (CRC) and the confirmation of a correct transfer will allow the compressed file in the DAS to be erased. If the connection is broken, the DAS will try again at the next opportunity until all data files in the temporary directory are transferred. If the modem connection is noisy or intermittent, the DAS will cease attempting until it detects more favorable conditions.

DATABASE DESIGN OVERVIEW

Data is transferred from each harvesting server to the main database computer by an automated computer program every three hours. The database computer is located at the Army Research Laboratory (ARL) Major Shared Resource Center (MSRC) at Aberdeen Proving Ground. The designated computer has 64 processors of which 16 are utilized for the VISION application. Each processor has one gigabyte of memory to work with. The MSRC provides the Oracle database where the data is loaded.

The design of the database deals with three basic areas. First the configuration file previously mentioned is loaded into tables. This portion of the database documents the operations of the DAS as well as the active event triggers, the events to be counted, and the definitions of the channels for both the histogram and time history files. The second portion documents the metadata associated with each file. All files contain a basic set of metadata such as configuration file identification, unique identification for each truck, data file start time, odometer, latitude and longitude values.

Additional file-type specific metadata is recorded with each file. For example, the triggered time history files include CWS target data and active trigger data. Histogram data files record the file closing time, odometer, latitude and longitude values. The third portion of the database is for the actual parameter data collected for that data file.

Each file that is created on the DAS has embedded in it the unique identification of the configuration file. This configuration file must be registered in the database before any of the files can be loaded into the database. When a new version of a configuration file is developed, before it is put on the system for distribution, it is loaded into the database. This allows for multiple configurations to be active in the field at any given time.

While access to the database is tightly controlled by a multi-step log-on procedure, the data are accessible through any web browser. A combination of JavaServer pages (JSP), servlets, and applications was developed to aid the user in accessing the required data in report or download format. Because the chosen database is one of the industry leaders there exist many third party tools available to aid in the manipulation of the data. Some of the identified requirements are composite histograms, histogram comparisons from similar events, and time history comparisons from similar events. Individual data files may be examined in detail and saved at the user's local computer in a common spreadsheet format.

CONCLUSION

Aberdeen Test Center's VISION initiative is an evolving test and evaluation tool designed to make the acquisition and utilization of data more timely and less costly. The implementation of embedded instrumentation interfaced with the appropriate communications that link the data to a database repository is proceeding with several Army programs. The opportunity to participate in this nationwide field operational test helped verify that the initiative is progressing and developing new tools. The advent of networked acquisition devices adds flexibility, scalability and expandability to acquisition systems. Analysts are providing input for improving the database query tools and user interface. On-going efforts are improving the initiative while providing valuable data to designers, users, and decision makers.