

Micro DAS

In-Vehicle Portable Data Acquisition System

FRANK S. BARICKMAN AND MICHAEL J. GOODMAN

The evolution of the National Highway Traffic Safety Administration's Data Acquisition System (DAS) for Crash Avoidance Research into a relatively inexpensive portable system (Micro DAS) that can be implemented in virtually any vehicle has opened up a wide range of research possibilities never before possible. Micro DAS is very small and can be installed directly into a test participant's own vehicle in a short time period. Its video recording system is capable of collecting over 22 h of full-motion video. Data collection can be triggered manually or based on events defined by the researcher. Micro DAS is also designed to collect antecedent data, allowing the information leading up to an event to be studied. These features allow the system to collect real-world information on driver behavior, driver and vehicle performance, and roadway environments in situ without concerns associated with vehicle familiarity or researcher presence. The Micro DAS philosophy, architecture, sensor array, and versatility are discussed in detail.

Given the diverse circumstances leading to motor vehicle crashes and the associated problem areas and issues, effective collision avoidance countermeasures can best be realized through comprehensive knowledge and understanding of both the events leading to crashes and the contributing driver, vehicle, roadway, and environmental factors. Likewise, with increasingly complex technologies being incorporated into vehicles, such as navigation systems, driver information systems, and wireless communications, there has been an associated increase in the demands placed on the driver and, as a consequence, a potential for increased risk of a crash. In an effort to enhance its capability to study wide-ranging problems and issues associated with the design and implementation of both crash avoidance systems and in-vehicle systems of convenience, NHTSA is developing a variety of analytical and hardware-based tools. These tools would allow the assessment of driver performance and behavior under a variety of circumstances and conditions in settings that either approximate the real world or are in fact the real world.

Significant advances in computational and sensor technology have resulted in capabilities that for the first time allow the evaluation of drivers and systems under truly naturalistic, in situ driving conditions. The need for such a capability is obvious given the frequent criticism of research in which the circumstances of data collection are questionable on the basis of realism and the highly controlled settings that are frequently used in such research. Furthermore, the need for field and operational testing of new in-vehicle technologies from the standpoint of effectiveness and safety often demands as realistic a setting as possible. With these requirements in mind, NHTSA has developed a family of vehicle instrumentation systems that allow a wide range of on-the-road testing and evaluation of both conventional technologies (e.g., mirror systems) and advanced tech-

nologies (e.g., rear-end crash avoidance systems, navigation systems). These systems, Data Acquisition System for Crash Avoidance Research (DASCAR) and Micro DAS, by design, are portable in that they can be installed in virtually any vehicle. This feature provides very desirable versatility in that it allows research to be carried out in a variety of test beds with a minimal investment in instrumentation. Other features of these systems are equally important and include the inconspicuous and unobtrusive installation of instrumentation and sensors, use of off-the-shelf technology, long-term data collection potential, extensive upgrade flexibility, and relatively low cost. In this regard, Micro DAS, the subject of this paper, offers the greatest cost-benefit ratio.

Micro DAS was a logical evolution of DASCAR, which focused on highly inclusive and complex data collection efforts in which a large number of variables could be addressed, including those associated with psychophysiological data (*1*). What was needed was a very low-cost system that would allow collection of truly naturalistic data, that could be installed in subjects' own vehicles in a relatively short period of time, but that would also allow the collection of a wide range of data, including video. Micro DAS was developed to fill the niche.

Naturalistic data are viewed as falling into three categories:

- *Baseline data*: Data that would represent the distribution of performance and behavior of interest characteristic of a given population of drivers;
- *Focused data*: Data that would be directed at evaluating a specific aspect, system, or device from the standpoint of its influence on driver behavior and performance; and
- *Near-miss and incident data*: Data that would focus on the occurrence of near misses and incidents that occur during driving, including antecedent events.

In each of these areas, data collection is associated with its own characteristic set of requirements and constraints for an acquisition system. The challenge was to develop a system versatile enough to address the wide range of features needed to support all areas. In the case of baseline data, a system should be capable of long-term acquisition or sampled acquisition under a given set of constraints (e.g., speed > 100 km/h, turn-signal activation). For focused data collection, the activation or use of the technology of interest (e.g., cellular telephone, automatic braking system) as well as antecedent conditions would be required, whereas for near-miss and incident data collection, appropriate triggering criteria (e.g., rapid steering rate, hard braking) would be necessary along with antecedent information. Within the framework of research already highlighted, availability of these capabilities would provide an invaluable tool for addressing a host of vital design and safety issues associated with both conventional and advanced technologies and would provide an excellent mechanism for validating the National Advanced Driving

F. S. Barickman, Vehicle Research and Test Center, National Highway Traffic Safety Administration, East Liberty, OH 43319-0337. M. J. Goodman, Office of Human-Centered Research, National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, DC 20590.

Simulator (NADS) currently under construction. Micro DAS was developed with these goals in mind. It should be noted that because of the very nature of naturalistic data collection and the use of drivers' own vehicles operated under normal, realistic, driving conditions, there is an opportunity to also study more visible contemporary issues such as intoxicated drivers and aggressive drivers in settings that would otherwise not be possible.

SYSTEM DESCRIPTION

Micro DAS is an integrated platform that consists mainly of commercially available, off-the-shelf components. The platform is broken down into two major systems, the analog and digital event recording system (ADERS) and the video event recording system (VERS). A block diagram of the two systems is shown in Figure 1. ADERS is responsible for collecting all engineering unit (EU) data, including data from analog sensors, digital inputs and outputs, as well as serial RS-232 devices. VERS is responsible for digitizing and storing video data.

Both systems are based on a small single-board computer (SBC). The SBCs feature an integrated peripheral component interconnect (PCI) IDE controller, a PCI super video graphics adapter (SVGA) display, a PCI network interface controller, floppy drive controller, a PC104 bus expansion connector, and a PCI bus expansion slot, all integrated onto a small circuit board measuring 12.7 cm by 20.32 cm.

ADERS

ADERS logs all of the analog and digital sensor data. It is composed of two analog input boards, a serial input board, and a digital input/output (I/O) board. The boards are based on the PC104 bus architecture. PC104 is a standardized bus that uses a 104-pin header connector and allows boards to be stacked together forming its own rugged bus without the use of a backplane (2). ADERS contains a fixed hard drive for control code and data storage and an LS-120 floppy drive for off-loading data on high-density media (120 MB). A small microcontroller is included in the package for power management. The system is powered by a DC-DC power

converter that is attached to the end of the PC104 stack and provides 50 W of regulated power.

The base configuration of ADERS allows data collection from 16 analog inputs at 14-bit A/D resolution. The system can be expanded to collect data from a maximum of 32 analog input channels by adding boards. For binary-type data, that is, to turn the signal on or off, 24 digital I/Os are available. These are configured for input or output on a byte basis. The standard ADERS setup uses 16 digital input lines and 8 digital output lines. The system also has five serial ports available for sensors, control of external devices, or both.

VERS

VERS is a real-time digital video recording system. It consists of an IPB MPEG-1 video compression board, a black-and-white (B/W) quad picture processor, four small B/W video cameras, and two large-capacity hard drives mounted into removable carriers. The MPEG-1 encoder has a programmable compression rate that can be set from 150 to 3,000 Kbps. Images are recorded in a 352 by 240-pixel frame with 16-bit red-green-blue (RGB) color depth and two channels of audio. From various tests of recording motion at different encoding rates, it has been determined that an optimal setting for decent quality video output along with reasonable compression is 1,000 Kbps. Using this setting with 14 GB of hard disk storage, the system can record for longer than 22 h continuously at 29.97 frames per second. This is approximately a 50:1 compression ratio.

SENSOR SUITE

The Micro DAS sensor suite is composed of a diverse variety of sensors that allow collection of a variety of parameters and their derivative measures. The system is generally installed in a subject's vehicle with the following list of basic core parameters:

- Global positioning system (GPS): latitude, longitude, speed, heading angle;
- Throttle position;
- Lateral lane position;
- Headway distance;
- Vehicle speed;

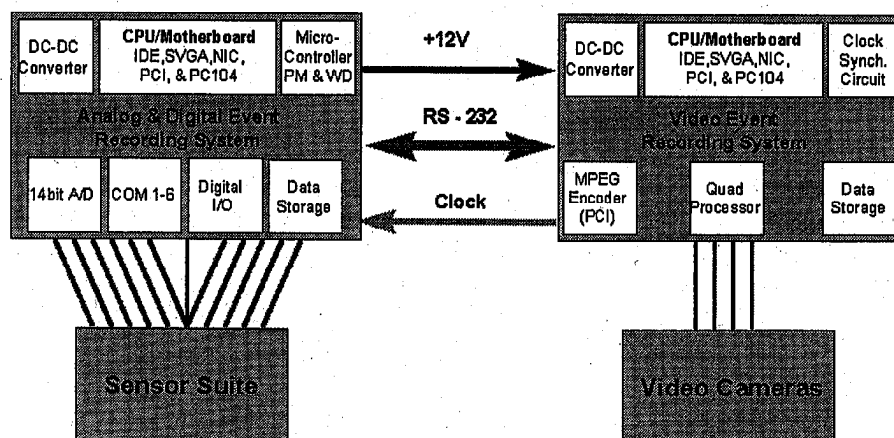


FIGURE 1 Block diagram of Micro DAS.

- Brake application;
- Lateral acceleration;
- Longitudinal acceleration;
- Vertical acceleration;
- Yaw rate;
- Hand wheel angle; and
- Turn-signal activation.

Other parameters and associated measures can be modified or added as needed to meet specific testing requirements. Some examples that have been previously implemented include

- Brake pedal force,
- Brake line pressure,
- Head position measurement,
- Variety of headway sensors [radar and infrared (IR) based], and
- Audio (two channels).

Micro DAS utilizes existing vehicle sensors, off-the-shelf transducers, and sensors that have been developed for specialized applications by NHTSA's Vehicle Research and Test Center (VRTC). Sensors and signals existing on the vehicle that are utilized include the throttle position sensor (TPS), vehicle speed sensor, brake light signal, headlight "on" signal, left and right turn signals, and an ignition-on signal. Connections into these are made in a nondestructive manner so that the sensor or factory cabling is not damaged.

Sensors purchased from commercial vendors include micro-machined silicone accelerometers, range finders, GPS receivers, and solid-state angular rate sensors. All of these are inexpensive, reliable, and available off the shelf from a variety of manufacturers.

Other sensors such as those that can measure lateral vehicle position and handwheel angle are not readily available as sensor pack-

ages off the shelf. Solutions for these measures that are inexpensive and easily installed have been developed by engineers at VRTC.

The VRTC lane-tracking system is a hardware-based design that can track the distance between a vehicle and a painted roadway marking in real time with a 60-Hz output. The system consists of a signal processing box and two B/W charge-coupled device (CCD) cameras. The cameras are installed with a downward-looking field of view on both sides of the vehicle (3). Depending on the camera's location and optics, operating range (how far laterally it tracks a line) and output resolution of the system can vary. For Micro DAS, the lane tracker is set up to track a line up to 3 m per side with better than 5-cm resolution and lane exceedances up to 0.6 m. The system works extremely well when average to above-average quality roadway markings are present, regardless if they are solid, dashed, yellow, or white. Tracking at night can be achieved by adding a light source for the CCD cameras. The lane-tracking system is economical, costing less than \$700 for parts. Figure 2 shows the output of the left and right trackers as the vehicle maneuvers during a lane change. At time period 58.8 min, the vehicle begins to execute a right-to-left lane change. This change is characterized by the overflowing of the value from low to high on the y-axis. The driver then switches back to the original lane at around time period 59.3 min, as characterized by the high to low overflow.

Without modifications to the vehicle, measuring handwheel angle accurately and installing the sensor unobtrusively have been problems for researchers in the past. Engineers at VRTC have developed a method utilizing an optical encoder that can measure handwheel angle with high precision. The sensor is installed under the dashboard and coupled to the handwheel by compressing a small wheel to the steering shaft. The shaft is built up to about the same diameter as the wheel on the encoder, eliminating any irregularities and forming it to be round. A simplified drawing of the

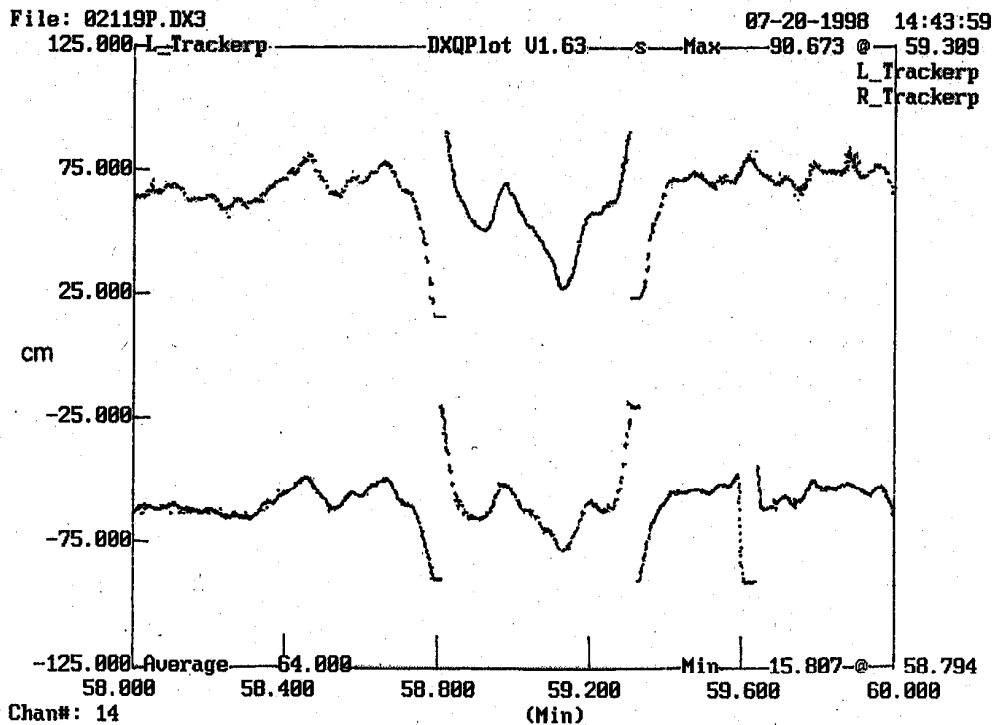


FIGURE 2 Output signal from left- and right-side lane trackers.

setup is shown in Figure 3. This design reduces the amount of mechanical noise typically seen by linear-coupled devices such as linear position transducers and can be easily installed in a wide variety of vehicles.

The sensor consists of a quadrature encoder with a quadrature decoder circuit, making the output of the encoder effectively 4,000 pulses per revolution. These pulses are fed to an up-down counter, which is then connected to a 12-bit digital-to-analog converter (DAC). The analog output voltage is recorded by ADERS. A DAC was chosen rather than a digital quadrature decoder board to keep the sensor universal with other data acquisition systems. It is capable of interfacing with any system that has an analog input. The design is intended to have the DAC overflow. Using software processing, the output signal is "unwound," creating continuous data from the non-continuous data with overflow. Figure 4 shows the output waveform of the DAC compared with the processed output. Using software processing, the sensor can provide precision handwheel data with relative 0.1-degree resolution while the vehicle is traveling at highway speeds. A zero is obtained dynamically through software based on the fact that over a period of time, a large percentage of the driving will be with the handwheel angle around zero.

Micro DAS utilizes miniature B/W video cameras. To achieve the highest level of unobtrusiveness possible, the cameras are installed within various components integral to the vehicle itself or, where necessary, installed within a common vehicle accessory. The camera locations will vary depending on the field view desired and whether nighttime recording is critical. These cameras are very economical and even have lenses for viewing wide-angle scenes and telephoto lenses for closeups. Video cameras generally take longer to install than the other sensors. Creating standardized mounting locations and fixtures saves time during installation of the system, although no single approach has been proved to be a universal solution.

The B/W CCD board cameras used in Micro DAS are capable of viewing IR around 880 nm with about 80 percent sensitivity. Use of

5 to 10 IR high-intensity light-emitting diodes (LEDs) provides sufficient illumination for viewing objects within 2 m from the camera. The LEDs are hard to make unobtrusive in the vehicle because of their need for surface area and specific lens placement. Several unique solutions have been developed to resolve this.

INSTALLATION

An integral aspect of the design of Micro DAS is provision for universal installation. The system, designed to be installed without making any permanent modifications to a vehicle, can be placed directly into a test participant's own vehicle. Because the system is intended to be installed in privately owned vehicles with no permanent modifications, the selection of sensors and support hardware was driven not only by cost and performance, but also by ease of implementation unobtrusively and nondestructively in a broad range of vehicle types. In many ways, "easy to install" and "unobtrusive" contradict each other.

In some cases, unobtrusiveness and inconspicuousness are sacrificed to shorten the amount of time needed to install the system. Such an example is the compass cam camera, an off-the-shelf compass modified to house a small B/W camera with an IR illumination source, designed to provide a video of the driver's face. The compass is mounted in the center of the dashboard, and the driver can see that it has been added to the vehicle, although not necessarily that it is a camera with IR LEDs hidden inside it. Alternative mountings would place the camera in the rearview mirror, an approach that has been proved in DASCAR. However, it has been difficult to adapt this approach as a universal installation method given the lack of mirror mount standardization and the short notice that often characterizes subject vehicle availability.

Installation of the entire Micro DAS takes an average of 1.5 person-days (12 h). Generally speaking, 95 percent of the system and associated sensors can be installed in a given automobile in about 6 h. The other 6 h is spent determining how to install the remaining 5 percent of the system since every vehicle presents new and different challenges because of the wide variety of automobile makes, models, layout arrangements, and body styles.

Currently, another day (8 h) is needed for preliminary testing before a system is released into the field for research. This time is spent confirming system operations and testing new developments implemented in the control code. The system is being developed and utilized in parallel processes. Much of this time will be eliminated in the future when the design is completed. Ultimately, the goal for installation is to have a subject's vehicle instrumented and ready to be deployed into the field within one working day.

Removing the system from a vehicle is rather easy. It currently takes about 2 h to completely remove a system and restore the vehicle to the same or better condition than when it was delivered.

EVENT-DRIVEN DATA ACQUISITION

In many research designs, data are collected continuously and then sorted, after the fact, to extract specific data of interest. Although this method of data collection is often needed to address specific issues of interest, it can be quite cumbersome with very large data sets. In addition to requiring a large amount of on-board storage, it can also require an extensive amount of time to scan and extract the pertinent information. An alternative approach is to sample data

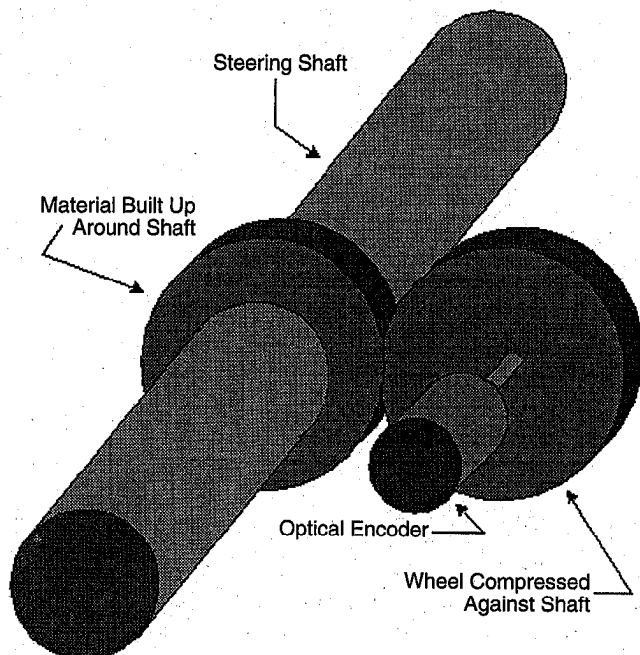


FIGURE 3 Simplified drawing of handwheel encoder installation.

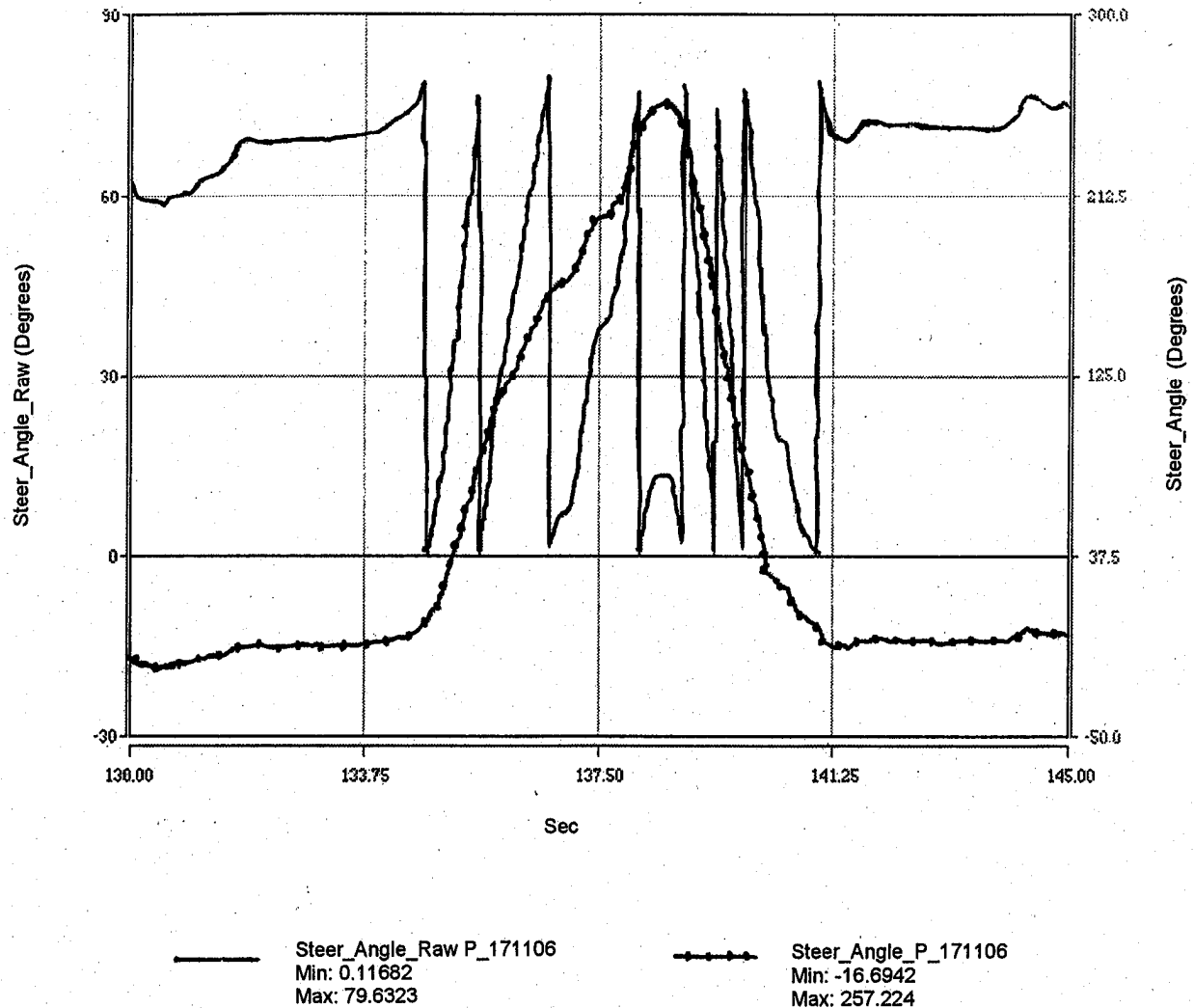


FIGURE 4 Continuous versus noncontinuous data from handwheel encoder.

based on events. By using predefined events, data can be collected in sets that contain only relevant information. Micro DAS is capable of triggering events based on sensor data, elapsed time, time of day, user-defined equations (as defined in the source code), and various Boolean combinations of these.

For example, if a researcher was interested in collecting data to characterize car-following episodes when vehicles were traveling on a highway at night, the system could be configured to collect data only when a headway sensor reported an object ahead, the vehicle was traveling more than 70 km/h, and the time of day was between 9:00 p.m. and 5:00 a.m. Configuring an event such as this with Micro DAS may not guarantee that all events of interest are captured, but this filtering does eliminate a good portion of the unwanted data and has the potential to greatly reduce the data reduction process.

DATA PRE- AND POSTTRIGGERING

On most occasions, the onset and evolution of an event are not the only or primary data of interest. For this reason, Micro DAS has the capability to pretrigger data collection or, in other words, record

antecedent data that define the conditions and actions preceding the event itself. The system is also capable of posttriggering, which enables the system to collect data for some specified amount of time after an event has occurred. For example, an experimenter could define the triggering point of a data collection event as a warning level from a collision avoidance sensor. When the warning was activated, the preceding 30 s of data leading up to the event would be stored to a file along with the event data and, if desired, data for a 45-s period following the event. This approach to data collection allows for more efficient data reduction since it eliminates the need to sort through large quantities of data collected. It is also ideal for collecting near-miss and incident data as well as more focused technology-oriented data (e.g., activation of a cell phone).

The current Micro DAS design is capable of buffering approximately 30 s of EU data depending on the number of channels being collected. Video data are currently not buffered, but this will be supported in the near future. The system can also be configured to collect data defining multiple events using the pre-and posttriggering scheme. These configurations can be easily modified to allow experimenters to look at a variety of questions while only collecting data for a single experimental series.

DATA HANDLING, ARCHIVING, AND REDUCTION

Data handling, archiving, and reduction are some of the most demanding tasks in dealing with information collected from any data acquisition system. A common data reduction burden ratio often found when reducing video data is 10 h reduction for every 1 h of data collection. This ratio does not even factor in the amount of time needed for handling and archiving the data. This ratio is a frightening number given that one Micro DAS is capable of collecting over 22 h of video data without any operator intervention. As mentioned earlier, recording video digitally using MPEG-1 compression results in an approximate 50:1 compression ratio. Although this ratio is quite good, it leaves a large amount of data to be stored and archived. VRTC is currently exploring approaches to automate this process.

Typically, using a manual approach, data are extracted from the system by transferring the contents of the removable hard drives to another hard drive on a base station computer. An operator then checks the removable hard drive to identify partial or lost files and attempts to restore them using software such as Microsoft's Scan Disk. After the drives have been checked, the operator verifies the transferred files manually, confirming that the data were copied correctly. The operator then begins to convert the Micro DAS files into a usable file format for plotting and processing, such as DX (VRTC file format), Matlab, or ASCII. When the conversion is complete, the operator begins to check EU data, confirming that channels were operating correctly. Finally, to ensure a safe data archive, the operator will then back up the data located on the base station hard drives to CDs, manually writing them one at a time (650 MB per CD) until the data set is completely archived.

Although this process is quite simple, it is labor intensive. As a consequence, VRTC has developed a framework to automate the process. Using this framework, the operator will only need to physically transport the removable hard drives from Micro DAS to the base station computer. Once the hard drives are installed in the base station computer, the user will only be required to initiate a Windows NT program that carries out the complete process automatically, copying all of the data from the Micro DAS hard drives to a local hard drive, scanning the removable drive for zero-length or corrupted files, converting the data, verifying that the data are valid, cleaning the removable hard drives, archiving the data through a robotic CD recorder, and then notifying the operator over a Novell-based network that the process has been completed.

Once the process is complete, the operator needs to remove the Micro DAS drives from the base station and place them back into the data collection system to complete the process. If any errors have occurred in the process, a text message is displayed on the monitor of the base station for the operator to review. Errors are also logged to a text-based file for later review and manual intervention.

This program currently does not have the ability to reduce the video data automatically, but it is anticipated that automated video data reduction will be feasible within the next several years. The program has been designed to hook into these routines when they are developed. Because the video data are stored digitally, it is conceivable that a software-based algorithm could scan the video data file and return the desired results automatically. One step toward automating the video data reduction has been demonstrated by researchers at the University of Michigan in Dearborn, who have developed a tool for querying MPEG video called COLUMBO. Under COLUMBO, they have successfully demonstrated the capa-

bility to query MPEG video for identifying lane changes and road curvature, all from a forward-looking road scene of an MPEG data file (4). In an extension of these techniques, routines could be developed that output data into the EU file that includes the time or frame when an event from the video occurred. These events could include where the drivers were looking, what the drivers were doing with their hands, when the drivers exceeded their given lane boundary, and so on.

COST

The current version of Micro DAS costs approximately \$8,900 (U.S.) in hardware and takes approximately 4 to 5 person-weeks to assemble. A breakdown of the components and their associated costs is shown in Table 1. These costs are based on previous procurements and on a quantity of one. Currently NHTSA has replicated eight systems for use within its research programs. A major portion of the assembly time is spent wire-wrapping circuits, building specialized cables in house, and fabricating custom-made enclosures. In the future this time could be greatly reduced by the design of printed circuit boards and by the outsourcing of cables and enclosures. Reducing the assembly time as well as building systems in larger quantity could greatly reduce the overall system cost.

LESSONS LEARNED WITH MICRO DAS

The utility of Micro DAS is not confined to subjects' own vehicles; the system is equally capable of serving as an experimental platform for controlled test track studies while providing exceptional versatility for testing in a variety of vehicles. Nevertheless, the greatest challenge has been to address the issues associated with use in subjects' own vehicles. Significant variations in vehicle style, type, and manufacturer along with the uncertainty of the mechanical condition of the subjects' vehicles have presented a number of unique and challenging issues. Although no modifications are made to vehicles that in any way compromise safety, vehicles are examined to ensure that they are safe to operate. Any minor problems are fixed before the vehicle is released for testing. If there are any major safety problems with the vehicle, it is not used for testing and is returned to its owner with a detailed description of the problems.

In some cases where vehicle design is such that it may not be possible to implement Micro DAS without some degree of modification, the approach adopted is to remove the original component and replace it with a modified component, restoring the original equipment at the conclusion of the data collection. Because of the time necessary to obtain spare parts, this approach works only when there is sufficient lead time to order parts, a situation that has proved the exception rather than the rule since subject availability is generally determined on short notice.

Another related area that has required careful consideration is informed consent. Three aspects must be highlighted. First, subjects need to understand that no modification is made to their vehicle that compromises safety. Second, they have the responsibility to drive as they normally would drive, and finally, the data, including video, may be used at the discretion of the researcher. Although subjects generally are curious as to the nature of the research, every effort is made to prevent the subject from learning the true intent of the data collection.

TABLE 1 Micro DAS Component Costs

Product	QTY	Unit Cost	Total Cost
Single Board Computer	1	\$547.00	\$547.00
Cable Set	1	\$74.00	\$74.00
CPU w/ cooling fan	1	\$130.00	\$130.00
16MB RAM	2	\$40.00	\$80.00
1+ GB Hard Drive	1	\$200.00	\$200.00
LS-120 Floppy Drive	1	\$90.00	\$90.00
50W Power Supply	1	\$350.00	\$350.00
Analog Input Board	2	\$345.00	\$690.00
Serial Input Board	1	\$239.00	\$239.00
Digital Input/Output Board	1	\$135.00	\$135.00
Cable Set for Input Boards	1	\$100.00	\$100.00
3 Axis Accelerometer	1	\$225.00	\$225.00
1 Axis Angular Rate Sensor	1	\$299.00	\$299.00
GPS Engine with Antenna	1	\$300.00	\$300.00
Headway Sensor (Laser based)	1	\$250.00	\$250.00
VRTC Lane Tracking System	1	\$700.00	\$700.00
Hand Wheel Encoder Circuit	1	\$100.00	\$100.00
Screw Terminal Board	2	\$69.00	\$138.00
Enclosure Metal	1	\$50.00	\$50.00
ADERS Subtotal			\$4,697.00
Single Board Computer	1	\$547.00	\$547.00
Cable Set	1	\$74.00	\$74.00
CPU w/ cooling fan	1	\$130.00	\$130.00
16MB RAM	2	\$40.00	\$80.00
Power Supply	1	\$350.00	\$350.00
7+ GB Hard Drive	2	\$350.00	\$700.00
MPEG Encoder Board	1	\$1,395.00	\$1,395.00
B/W Quad Video Processor	1	\$299.00	\$299.00
B/W Video Board Camera	4	\$133.00	\$532.00
Enclosure Metal	1	\$50.00	\$50.00
VERS subtotal			\$4,157.00
Micro DAS Total			\$8,854.00

One issue that has repeatedly been raised relates to the knowledge by the subject that his or her behavior is being recorded and the question of whether this knowledge influences driving. The authors' experience has been that after only a short period of time, perhaps an hour, subjects behave as they normally would, a conclusion based on the presence of behavior in the vehicle that one would not expect an influenced subject to exhibit.

Finally, ensuring the continual integrity of the data collection has proved to be a real challenge. The loss of a single sensor can jeopardize an entire data set for a subject. Since subjects may be on the road for some time, the loss of time and the expense of that loss can be quite substantial. Since subjects are not informed of the nature of the data collection and the sensor locations are generally unknown to them, they would not know if something went wrong and could therefore not inform the researcher. In this regard, two problems of note that have surfaced are the importance of cable integrity and the adequacy of video camera positioning and attachment. Ultimately, the solution may be to use internal checks that alert a subject that something is wrong and that the researcher should be contacted, regular check-ins with the researcher, or the use of a wireless (e.g., cellular phone) communications link to the vehicle to check system functioning.

FUTURE MICRO DAS ENHANCEMENTS

With technology changing rapidly in today's industry, there are many enhancements that can be added to Micro DAS that were not available during the initial design phase of the system. These enhancements will be added as they are needed in future NHTSA research programs. Possible enhancements include event recording from eight multiplexed video cameras, extending the video recording time, integrating the ADERS and VERS into one platform, and extending the duration of antecedent data collection.

The current design of Micro DAS is limited to four video cameras. At a minimal cost, it is possible to add up to eight video cameras to the system. They would be multiplexed by a microprocessor-controlled switch that would allow any of them to be output to one of the four quad picture processor inputs. Camera views would be dynamically switched on the basis of the data collection events.

Larger hard drive storage capacities are available today that cost the same as or less than models used in the existing Micro DAS. As a result, it is now possible to store over 28 h of video on a single drive. The system cost and size will be reduced, resulting in a single-drive system versus the current dual-drive setup. Another possibility would be to use two of the larger-format drives. This system would

enable the recording of over 56 h of data without the addition of size or cost to the current design.

It may be possible to integrate both ADERS and VERS into a single platform. Preliminary testing has shown that it is feasible to collect sensor data as well as video data operating on the same single-board computer. Integrating the two systems will dramatically reduce the cost and the size of the system.

As mentioned previously, antecedent data collection is currently limited to the sensor data. In the near future, the ability to buffer video data before an event will be included. In addition, it is technically feasible to extend the amount of antecedent sensor and video data collected. It is believed that the duration can be extended to six times the current capacity. This would allow approximately 3 min of sensor and video data to be stored leading up to an event.

CONCLUSIONS

Micro DAS is an economical system and versatile tool to support the data collection needs for a wide variety of transportation research. The system is unique in that it can actually be installed into a subject's personal vehicle, be inconspicuous to other drivers, and be unobtrusive to the driver. Micro DAS features, such as extended

video data collection, event triggering, and the system's ability to pretrigger data collection, allow researchers the flexibility to collect operational field data over long time periods without intervention. The ability to collect truly naturalistic data over extended periods of time is viewed as an important capability for supporting both human factors and vehicle engineering research covering conventional technologies, advanced technologies, as well as high-visibility driver behavior, such as aggressiveness and intoxication.

REFERENCES

1. Carter, R. J., and F. S. Barickman. *Data Acquisition System for Crash Avoidance Research*. Peer Review of the National Highway Traffic Safety Administration Program. 53-63. Intelligent Transportation Society of America, Washington, D.C., 1995.
2. PC/104 Consortium. *PC/104 Specification Version 2.3*. Available at <http://www.controlled.com/PC/104/consp5.html>, June 1996.
3. Barickman, F. S., and D. L. Stoltzfus. *A Simple CCD Based Lane Tracking System*. SAE Paper 1999-01-1302. Society of Automotive Engineers, Warrendale, Pa., 1999.
4. Kreucher, C. *A Tool for Query and Analysis of MPEG Encoded Video*. Master's thesis. University of Michigan, Dearborn, 1997.

Publication of this paper sponsored by Committee on Simulation and Measurement of Vehicle and Operator Performance.