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Development and Evaluation of An In-Vehicle Information System*

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ABSTRACT

In this paper, we introduce an In-Vehicle Information System (IVIS) which will manage messages from a variety of Advanced Traveler Information Services (ATIS) devices which can be installed in a road vehicle. The IVIS serves as the interface between the driver and the driving information environment. Increasingly, aftermarket systems, such as routing and navigation aids, are becoming available which can be added to vehicles to aid in travel and/or the conduct of business in the vehicle. The installation of multiple devices, each with its own driver interface, increases the likelihood of driver distraction and thus the risk of an accident. The goal of this project is the development of a fully-integrated IVIS which will filter, prioritize and display highway and vehicle information safely and efficiently, while also providing an integrated driver interface to a variety of ATIS information sources. Because these devices will be integrated into IVIS as components, they are referred to in this paper as IVIS subsystems. Such a system, using modern digital technology, will tailor information both to the driver's needs and to the driving environment. A variety of other efforts, both in the U. S. and abroad, either have been completed or are nearing completion, and the results of these efforts will be incorporated into this present system. IVIS must perform three high level functions (Tufano, et al, 1997). It must 1) interact with (ATIS) subsystems, 2) manage information, and 3) interact with the driver. To safely develop and evaluate such a device, a platform must be devised which permits testing in an off-road setting. The development and testing of an IVIS is proceeding along two lines. First, a computer network has been built which emulates the functioning of various ATIS devices which send information to a PC which serves as the IVIS. The IVIS PC serves as the device on which the information management logic is developed and tested. The second line of development is a dual-task platform on which to develop and evaluate the driver interface -- both for display and for control input. The platforms to carry out this work are described, along with the plans to integrate actual ATIS subsystems into the platform.

INTRODUCTION

Previous work has described the development of functional requirements and system concepts for an In-Vehicle Signing system, to display roadside signs and markings inside the vehicle in a manner which enhances their saliency, perceptibility and comprehensibility [Spelt, et al, 1996, Tufano, et al, 1996a, 1996b]. These goals are accomplished by a process of selectively filtering and prioritizing the sign information to be displayed, and then by a timely display of the information with an appropriate saliency. An important and logical extension of that work is discussed in this paper and a companion one [Tufano, et al, 1997], which discuss aspects of the development and testing of an In-Vehicle Information System (IVIS). IVIS offers a radically

different approach to providing drivers with the information they need to complete their journeys in a safe, orderly, and expeditious manner. Currently, drivers visually gather this information, mostly from sources beyond their windshield, and partly from information displays inside the vehicle (such as the speedometer and fuel gauge). Increasingly, aftermarket systems are becoming available which can be added to vehicles to aid in travel and/or the conduct of business in the vehicle. Examples of currently available systems include navigation and route guidance (N&RG), cell phones and pagers -- systems which can be found increasingly often in rental cars, for example. Radar detectors are now being marketed which not only warn drivers of radar speed monitoring, but are capable of providing safety warnings about various potentially hazardous road conditions, by modulating the radar signal to carry brief messages.

Advanced Traveler Information Services, which provide information from the infrastructure to the vehicle, constitute an important component of the national ITS effort. ATIS-related highway and vehicle information includes, but is not limited to, roadway and weather safety advisory warning, real-time traffic information, routing and navigation, and "yellow pages" and other motorist services. As more and more ATIS services come on-line, additional devices to provide this information in the vehicle will be marketed. The installation of multiple devices, each with its own driver interface, increases the risk of driver distraction from the primary task -- driving -- and thus increases the risk of an accident. The goal of the IVIS project is the development of a fully-integrated In-Vehicle Information System which will manage this information and provide an integrated interface to these devices, thus permitting the driver to operate the vehicle safely and efficiently. IVIS, using modern digital technology, will tailor information to both the driver's needs and to the driving environment, and be cost-beneficial, while giving attention to human performance benefits, as well as to technology developments. An IVIS must convey the information in a manner which enhances the information's quality, utility, and meaning. Furthermore, it must perform this function in a way which greatly assists rather than interferes with the difficult task of driving.

IVIS-related guidelines and standards

Over the past few years, efforts have been under way in the U. S., Europe and the Orient, to develop ATIS- and IVIS-related services and subsystems, along with guidelines and standards on their use. In the U. S., two IVIS-related efforts will have a significant impact on IVIS development. One is the Federal Highway Administration-sponsored development of human factors guidelines for ATIS and CVO, presently being conducted by the Battelle Seattle Research Center. Similarly, other efforts have been completed by the University of Michigan Transportation Research Institute, and standards are under development by committees of the SAE, the IEEE, and ITS America. The principles, guidelines and standards resulting from these and other efforts can be implemented in the IVIS in order to explore their impact on the development and use of such a system.

In a particularly important effort, a committee of the SAE is engaged in the development of standards for an ITS Data Bus (IDB, see Kirson and Scott, 1996). This bus is intended to serve the needs of consumers who wish to add electronic devices to their vehicles, including both entertainment and ATIS-related units. The goal of the IDB is to provide plug-and-play capability,

while preserving the integrity of the vehicle bus, with its mission-critical data. If this effort leads to a SAE standard, the IVIS system development platform described below will implement at least some aspects of the IDB -- the application layers of the ISO's Open Standard Interface. To the extent that some development and testing of these driver information services and ATIS-related subsystems have already been accomplished, they have been done independently of one another without consideration of the potential negative effects of such non-integrated services on the driver. This project focuses on creating such an integrated perspective. Ultimately, the IVIS project should foster the successful deployment of IVISs. The project will support this goal through the development of an IVIS prototype which treats and presents driving-related information in a safe and efficient manner.

IVIS SYSTEM CONCEPT AND DESIGN

The primary purpose of an IVIS is to provide the interface between the driving milieu and the driver, thereby managing both the information output to the driver and the driver's control inputs to the various IVIS subsystems. Success in these tasks will reduce the driver's workload, while providing him/her with the means to obtain and comprehend information necessary to successful completion of the trip. Because the IVIS must be capable of accommodating a variety of ATIS subsystems, as well as a variety of driver and mission needs and preferences, the system must be flexible and easy to use. Flexibility is accomplished through both hardware and software modularity. Ease of use is accomplished by means of the application of Driver-Oriented Systems Engineering (DOSE). The underlying principle of DOSE is simple: each system engineering decision is made only after consideration of the impact of that decision on human use of the system. There is obviously a wide range of decisions to be made in the design of a system such as the IVIS, in terms of how much impact the decision has on driver use -- some decisions have no impact beyond whether the system functions or fails, whereas others directly impact driver use. In between these two extremes, however, are decisions which may impact driver use in ways which are not immediately apparent, and these are the ones which contribute to a highly successful system when they are properly considered and decided during system design and prototyping, rather than as an afterthought.

The In-Vehicle Information System

IVIS must perform three high level functions (Tufano, et al, 1997). These three functions are depicted within the IVIS context in Figure 1, which shows a sampling of ATIS subsystems along with their communication links with the infrastructure, the system interconnection inside the vehicle, and the IVIS block which manages information and provides the driver interface. The IVIS must interact with (ATIS) subsystems (part A of Figure 1), manage information (B), and interact with the driver (C). The "gateway" is a mechanism proposed by the SAE ITS Data Bus committee. It functions to protect the vehicle bus from corruption by information which otherwise might be put onto the vehicle bus by any of the subsystems. It also provides information from the vehicle which is needed by the IVIS and/or the ATIS subsystems to perform the desired operations (e.g., the N&RG subsystem needs vehicle speed and possibly wheel information from the antilock brake system).

In order to communicate with each other, the IVIS and the driver, subsystems must be connected to the IVIS by means of either a data bus or by a point-to-point wiring scheme, as shown in Figure 1 by the indicated component. Ultimately, this connection is expected to use the IDB specified by the SAE standard. In this arrangement, communication between the vehicle and the infrastructure is performed by the various subsystems, each with its own communication path, as detailed in the National Architecture. The subsystems, in turn, do whatever information processing they are designed to do, and then send the prepared information to IVIS to be presented to the driver. The various subsystems can also communicate with each other on the data bus. For example, the yellow pages subsystem would need to tell the N&RG subsystem where a particular business is located, so that the N&RG subsystem can direct the driver to that location. In addition to the information management and presentation functions, IVIS also provides the input mechanism between the driver and the various subsystems. Such input might consist of the intended route for the N&RG subsystem or the desired phone number for the cell phone. This input is received by the IVIS and routed to the appropriate subsystem.

The information management function, performed within the IVIS, is a logical manipulation of the information received from the variety of subsystems connected. This function requires a system which accounts for driver preferences and needs, as well as taking into account the source of the information and its relative importance. Thus, a warning from a collision avoidance subsystem would take precedence over a message received by a pager. These functions can be performed by a modular rule base which has been carefully developed and thoroughly tested using the development platform discussed below. A detailed exposition of these functions is presented in the Tufano, et al (1997) paper on IVIS functional requirements elsewhere in these proceedings.

Driver interaction includes both information presentation and driver input. Information presentation is the direct and expected outcome of the information management functions. Driver input permits the user to enter route and destination information, as well as various filtering and prioritization preferences, prior to or during the trip. In addition, yellow pages requests and input to the cell phone or other personal communication subsystem devices must be possible. The nature of the input devices and procedures will be explored in the IVIS development platform.

IVIS DEVELOPMENT AND TESTING EFFORTS

Development and evaluation of the IVIS is proceeding on a dual track. The system integration and rule base development is done in a platform which emulates an integrated system which will be found on vehicles in the future. Driver interface issues are explored in a context which permits work on both perception-reaction time and dual-task performance.

System Development and Demonstration Platform

The system development platform comprises a number of personal computers, both high- and low-end, linked via ethernet LAN, with a high-end PC serving as the IVIS computer. This system is shown in Figure 2. The IVIS PC provides for the development and testing of the rule base which performs the information management and display. The scenario generator provides the network with a simulated trip, either a sequence of events and timing from an actual trip, or a

fictional trip which produces the types of situations needed to test the functioning of the logic and display routines of the IVIS. The other PCs in the LAN serve to emulate the functions of various ATIS subsystems, as indicated in the illustration. In its simplest operation, the development platform is driven by the signals broadcast to the LAN by the scenario generator, which provides the event signals for a trip. These signals are received by the other PCs in the LAN, which then emulate the functions of the ATIS subsystem they represent by sending appropriate messages into the LAN. These messages are, in turn, collected by the IVIS PC and processed for display, performing the information management functions described above.

For example, as the simulated trip proceeds, the scenario generator would "announce" that the vehicle is approaching Main and Elm streets. The N&RG subsystem would then send a message to "turn left at Main & Elm", while the safety warning subsystem (SWS) might be programmed to announce that a fire truck is approaching along Main from the left. These messages, along with others produced by any of the other subsystems, are then processed for display by the IVIS PC. Using this development platform, two goals can be accomplished. First, the information management functions of the IVIS can be developed, tested, and refined. Second, the platform serves as a demonstration mechanism to illustrate to visitors the benefits of IVIS information management, as well as permitting visitors to comment on what they observe.

Integration of Actual ATIS Subsystems

As development progresses, it is important to be able to evaluate the performance of the IVIS as it interacts with actual ATIS subsystems. To accomplish this, the ATIS units can be inserted into the LAN, either as substitutes for one of the PCs, or using the PC as an interface to the LAN. For example, a microwave receiver embodying the SWS message delivery capability has been integrated into the development platform through a two-way RS232 port. This data port permits the radar unit to send its messages into the PC, which, in turn, transforms the messages into a form to be put onto the LAN, from where the IVIS PC obtains them for processing and appropriate display. The two-way RS-232 port permits the detector to be triggered by the scenario generator through the LAN. For full feasibility testing, the detector can also be triggered by a reduced-power radar transmitter situated near the receiver. As IVIS development proceeds, more and more actual subsystems will be integrated in the emulation network, using the SWS microwave receiver as a model.

An additional consideration for use of the development platform is the implementation of the SAE IDB protocol. Due to the limited capacity of the processors in some of the potential IVIS subsystems (e.g., a pager only uses an eight-bit processor), a network protocol much less complex than the ethernet is required. Therefore, use of the ethernet in the development platform will restrict implementation to only the application and presentation layers of the ISO's Open System Interface standard. This is entirely adequate for development of the IVIS logic and high-level functioning. However, in order to implement the entire SAE IDB protocol, a simpler network protocol must be implemented. This will be accomplished through the installation of a communications network simulation on the IVIS PC.

Driver Interface Development and Evaluation

The other track of the IVIS development and testing process focuses on developing and evaluating the driver interface. This track represents the bulk of the human factors aspects of the project, presenting information in a manner which is demonstrably helpful to the driver. This process proceeds in parallel with the platform development and testing. All of the many aspects of the driver's interaction with an IVIS must be evaluated: information perceptibility and intelligibility, display timing and mode, and the driver's inputs to the system for indicating trip goals and destinations, as well as personal preferences.

Empirical evaluation of driver performance requires testing in at least two different contexts. The first is in a simple perception-reaction time paradigm, done on a workstation, in which stimuli (such as N&RG messages or traffic signs) are presented, to which individuals respond as quickly and accurately as they can. This type of reaction time paradigm can require only simple stimulus detection, or can involve a choice between two or more stimuli, with a differential response required, depending on instructions and context. This type of testing can indicate the ease or difficulty of a driver's perception of the presence of the message, as well as how easy or difficult it is to interpret the meaning of the message.

A dual task evaluation paradigm involves the determination of the extent to which particular messages or other stimuli presented by the IVIS distract the individual from a primary task. When the IVIS is installed in a vehicle, of course, the primary task is to drive the vehicle. However, before these devices can be evaluated on the road, a rigorous process of testing and evaluation must be carried out in the safety of a stationary evaluation platform such as the one described in this paper. In the case of the IVIS evaluation, this is accomplished by determining baseline performance on a primary task, and then introducing various IVIS-managed messages and signals while continuing to assess performance on the primary task. To the degree that primary task performance declines, the IVIS information distracts the "driver". Such an evaluation process is the first step in the process which leads ultimately to the testing and evaluation of IVISs in actual vehicles prior to their being deployed to the motoring community.

SUMMARY AND CONCLUSIONS

The development and testing of an In-Vehicle Information System represents a vital contribution to the implementation and deployment of the Advanced Traveler Information Services component of the Intelligent Transportation System in the United States. It provides the opportunity to evaluate a wide variety of user-related and system integration issues in a context which provides systematic and coherent empirical evidence about the impact of displaying ATIS information in a managed and driver-friendly way, as opposed to permitting several of these devices to operate independently and simultaneously. Without such an effort, which is heavily dependent on contributions from the various ATIS device manufacturers, the installation of multiple units inside a vehicle is likely to result in a confusing and distracting environment in which to drive. This effort also permits implementation of standards, guidelines and other user-related or system concepts in a context which is free from the risks of doing such testing on the road. It thus provides an important early step in the ultimate deployment of a safe and effective information management system.

A significant aspect of the project described in this paper is the outreach effort which invites involvement of a variety of manufacturers of ATIS subsystems. This participation of representatives of the private sector provides a number of benefits both to the participants and to the IVIS project. The participants have the opportunity to provide a periodic critique of the IVIS project, and to share their insights into how these subsystems might best be integrated. They, in turn, benefit from the insights gained by integrating a variety of different systems into the IVIS, and can gain experience by participating in the integration efforts in the IVIS platforms. The successful design and implementation of an IVIS must involve the efforts of vehicle manufacturers, ATIS information system manufacturers, and the efforts of the system integrators and standards-makers who help bring the whole process together.

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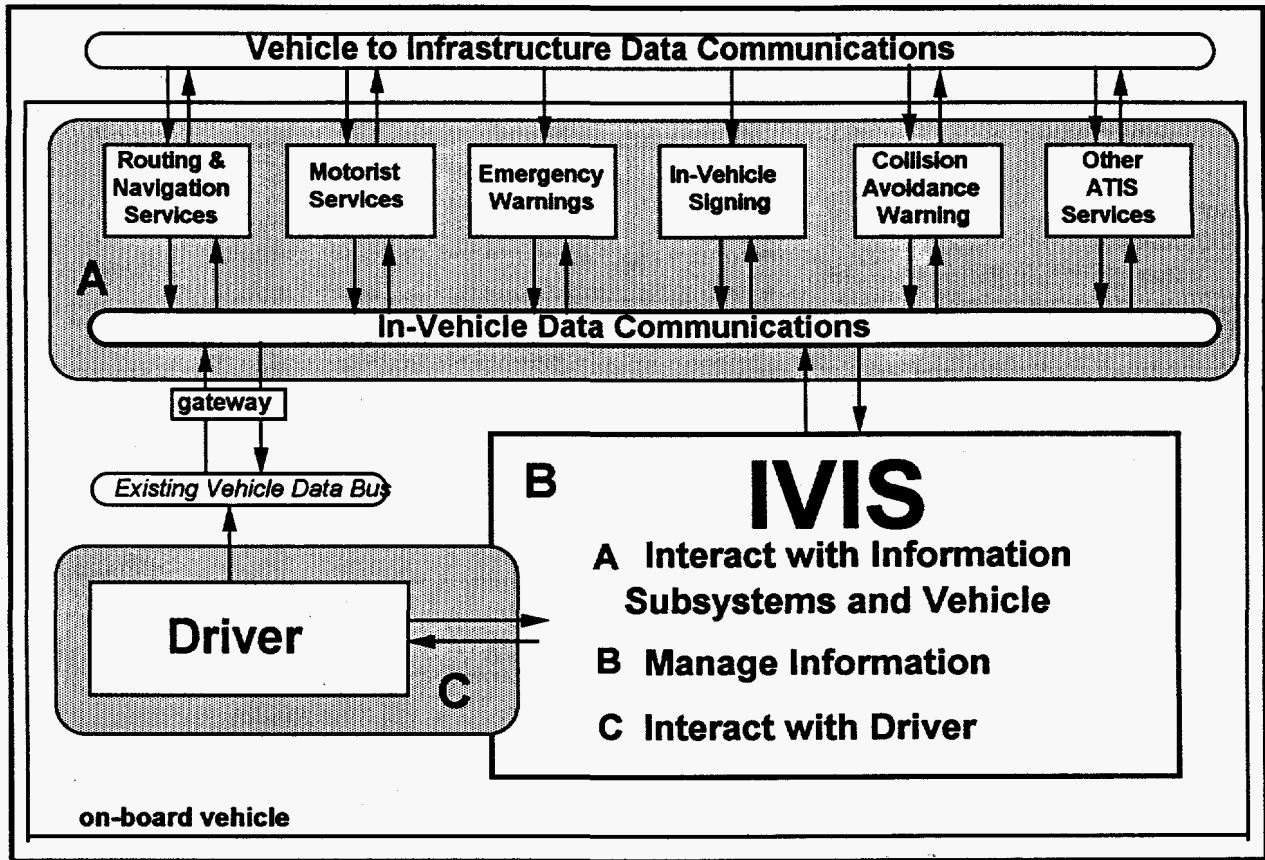


Figure 1. IVIS diagram, showing relationships between IVIS, the various ATIS subsystems, and the existing vehicle data bus with the proposed IDB gateway.

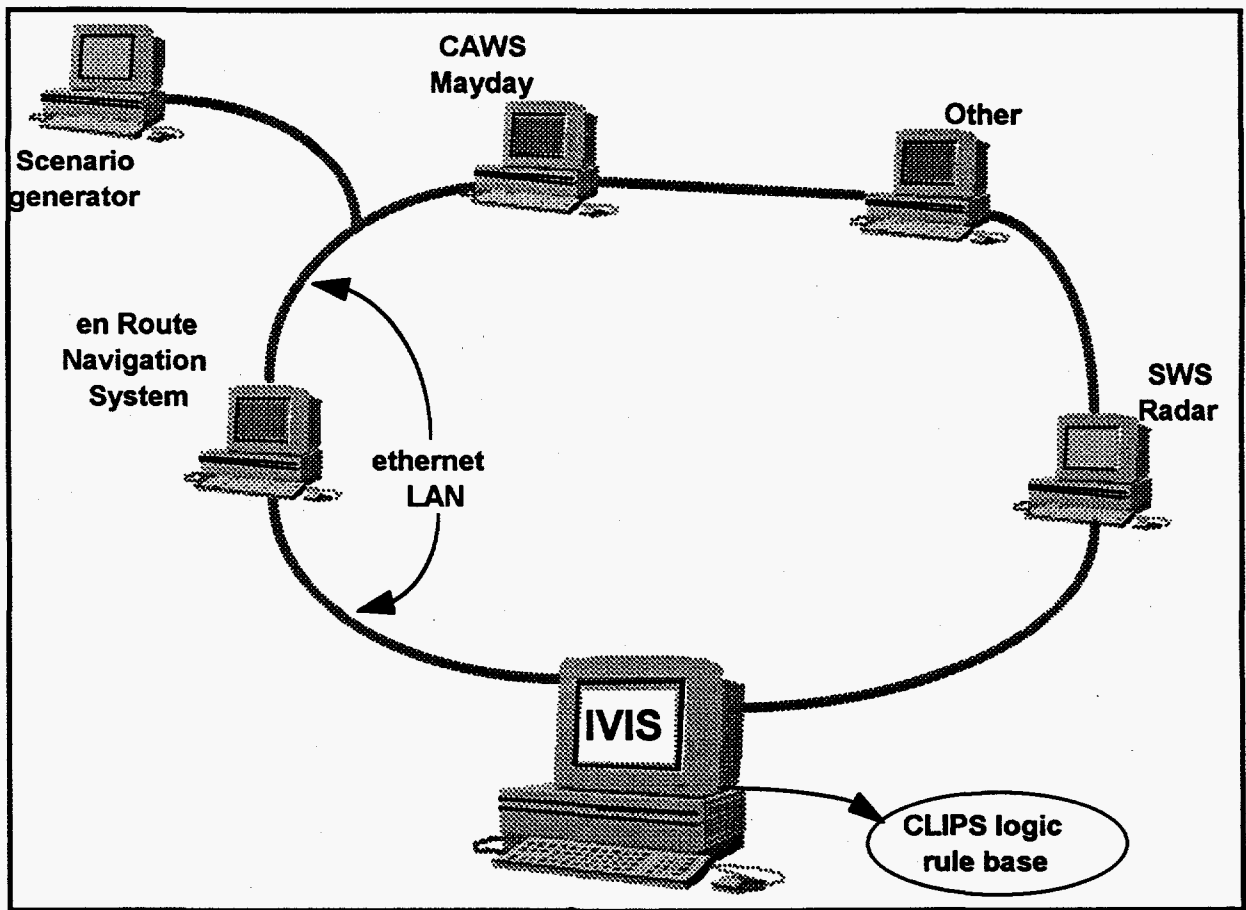


Figure 2. IVIS system development and demonstration platform.