APPLICATION OF A VIDEO ANALYZER FOR THE SAFETY EVALUATION OF AN INTELLIGENT CRUISE CONTROL SYSTEM

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ABSTRACT

This paper describes the application of a video analyzer that was developed and used to evaluate the safety impact of an Intelligent Cruise Control (ICC) system. Naturalistic driving data were obtained from 10 vehicles identically equipped with the ICC and data acquisition systems. Volunteer drivers participated in the Field Operational Test (FOT) which was conducted in southeastern Michigan. The video analyzer was developed to assist in the determination of a set of driving scenarios, close calls, and driver reaction times for the driver test data.

The ICC FOT was the result of a cooperative agreement between the National Highway Traffic Safety Administration (NHTSA) and the University of Michigan Transportation Research Institute (UMTRI). Other parties contributing to the field operational test were Leica AG, the Michigan Department of Transportation, and Haugen Associates. The Volpe National Transportation Systems Center (Volpe Center) with support from Science Applications International Corporation (SAIC) conducted the independent evaluation for this FOT.

INTRODUCTION

The Intelligent Cruise Control (ICC) Field Operational Test (FOT) consisted of 108 drivers, who had the ICC equipped vehicles for either two or five weeks. During the first week of the test, only manual control and conventional cruse control were available to the drivers. During the remaining weeks, manual control and ICC were available to the drivers. While the FOT was based in Ann Arbor, Michigan, the drivers were not restricted on where they could travel, as long as their travel was within the continental United States.

A major source of data collected in the ICC FOT was the video data recorded using the on-board camera. The video data recorded were stored as video clips. There were two types of video clips recorded - Exposures and Episodes. An exposure video clip has a duration of 2 seconds and was recorded once every 5 minutes that the vehicle was on. An episode video clip has a duration of 30 seconds and was recorded not on a regular basis, but whenever one of the video trigger thresholds was exceeded. Brake interventions, near encounters and a press of the concern button all had the potential of triggering the recording of an episode video. For brake interventions (triggered by deceleration > 0.05 g) and near encounters (required deceleration to ensure 0.3 sec headway > 0.05 g), the video was recorded for 15 seconds before and 15 seconds after the event which triggered the video to be recorded. Pressing the concern button press was programmed to capture the 30 seconds of video prior to the concern point.

In determining the ways in which the data available from the FOT would be analyzed, the evaluation team specified several different measures that were only available or were most easily measured through analysis of the video clips. The evaluation team realized that there would need to be some formal procedure for completing this analysis which would result in consistent and accurate recording of the measures of interest. It was this identified need which spawned the development of the video analyzer.

The data classifications resulting from the use of the video analyzer were stored in a data base which was linked to the FOT evaluation data base. The evaluation data base is a customized data base developed from the raw numerical data collected in the FOT. The customized data base includes classification information from other tools developed by the evaluation team (road class, level of land use, level of service). In developing the customized evaluation data base, the raw data were manipulated and sampled to provide more manageable data accessibility and analysis.

This paper describes the video analyzer's purpose, interface design, and primary classification methods, and provides some sample applications using preliminary ICC FOT data. The paper also discusses potential extended uses of the tool.

PURPOSE

The purpose of the video analyzer is to allow a human to classify visual data in an efficient, consistent and accurate manner. Potentially, use of a computer interface decreases the effort involved in recording/using the classification data as it allows automatic recording of classifications without manual annotation, and can format the classification data without requiring further manual input for use in the evaluation. In addition, the use of a computer interface allows the analyst to view certain numerical data variables to aid in deciding between particular classifications.

INTERFACE DESIGN

The video analyzer interface was designed, in iterative fashion, by and for the ICC FOT evaluation team, to meet the data needs of evaluation and the functional needs of the particular video analysis required of the evaluation. In order to determine these functions, members of the evaluation team reviewed the project study plan to determine exactly what information needed to be recorded. A movie viewer was used to run through a set of video clips, and classified those video clips using a pencil and paper to record the required information. The paper and pencil method proved to be tedious and redundant. This procedure did, however, provide many insights on what functions the video analyzer would need to provide, what information the tool would need to provide, and what information the tool would need to record.

Separate screens were needed for analyzing exposure clips and episode clips, to reduce confusion and to help the video analyst concentrate on the specific measures needed from each type of video clip. Specifically, an exposure video classification interface was devised to classify road class and level of service. The episode video classification interface was drawn up to classify driving states and close calls (frequency, severity and proximity), and measure response times. Both interfaces would be used to identify whether or not the video clip was a weather event (rain, road spray or snow) as these events can lead to inaccurate data being recorded.

The detailed design of the interface screens, and their underlying programming and data flows, were addressed through a series of prototypes. Basically, it was decided that the episode interface would need to provide information on what triggered the video to be recorded, the magnitude of the triggering event, and a timeline or time display to track the time into a video clip. On the remainder of the screen, several of the variables collected by the ICC vehicle were displayed to help differentiate between different driving situations and to help accurately measure response times. The consensus on the most useful variables were:

- the range vs. the rate of change in range to the vehicle being tracked by the ICC equipped vehicle;
- the velocity of the ICC equipped vehicle, V;
- the velocity of the vehicle being tracked by the ICC vehicle, Vp;
- the ICC equipped vehicle's throttle;
- the rate of change in range to the vehicle being tracked by the ICC equipped vehicle;
- tracking, a logical variable which is 1 when a vehicle is being tracked; and
- brake, a logical variable which is 1 when the brake is being applied.

The most useful way to represent these variables was to have them plotted on the screen and time synchronized with the video clip.

With respect to the exposure interface, it was not necessary to provide any additional information on the driving situation to the analyst, other than the actual exposure video clip.

Sample episode and exposure classification screens from the video analyzer are shown in Figures 1 and 2, respectively.

CLASSIFICATION – EPISODE VIDEO CLIPS

The general procedure followed by the video analyst in classifying an episode video clip is outlined in Figure 3. Each step of this procedure is described individually in the sub-sections below.

Usability

The usability of a video clip is determined by the clarity and content of the captured video. If the events captured in the video clip are not discernible due to weather, or no events occurred during the clip (for example, a car sitting in a parking lot), then the clip is labeled unusable by selecting the "unusable" button. Once a clip has been labeled unusable, no further analysis is required, with the exception of determining whether or not the clip showed evidence of being a weather event.

Driving States

Four driving states have been identified as being of interest to this study (Robinson, et al., 1997). They are:

- following a same speed target vehicle;
- closing on a target vehicle;
- separating from a target vehicle; and
- cruising.

The first three states represent non-cruising states (lead vehicle present) and can be differentiated accurately using algorithms created by the evaluation team. For this reason, the analyst chooses between two simplified driving states, cruising (no lead vehicle present) and not cruising. Driving states are identified by selecting the appropriate driving state button.

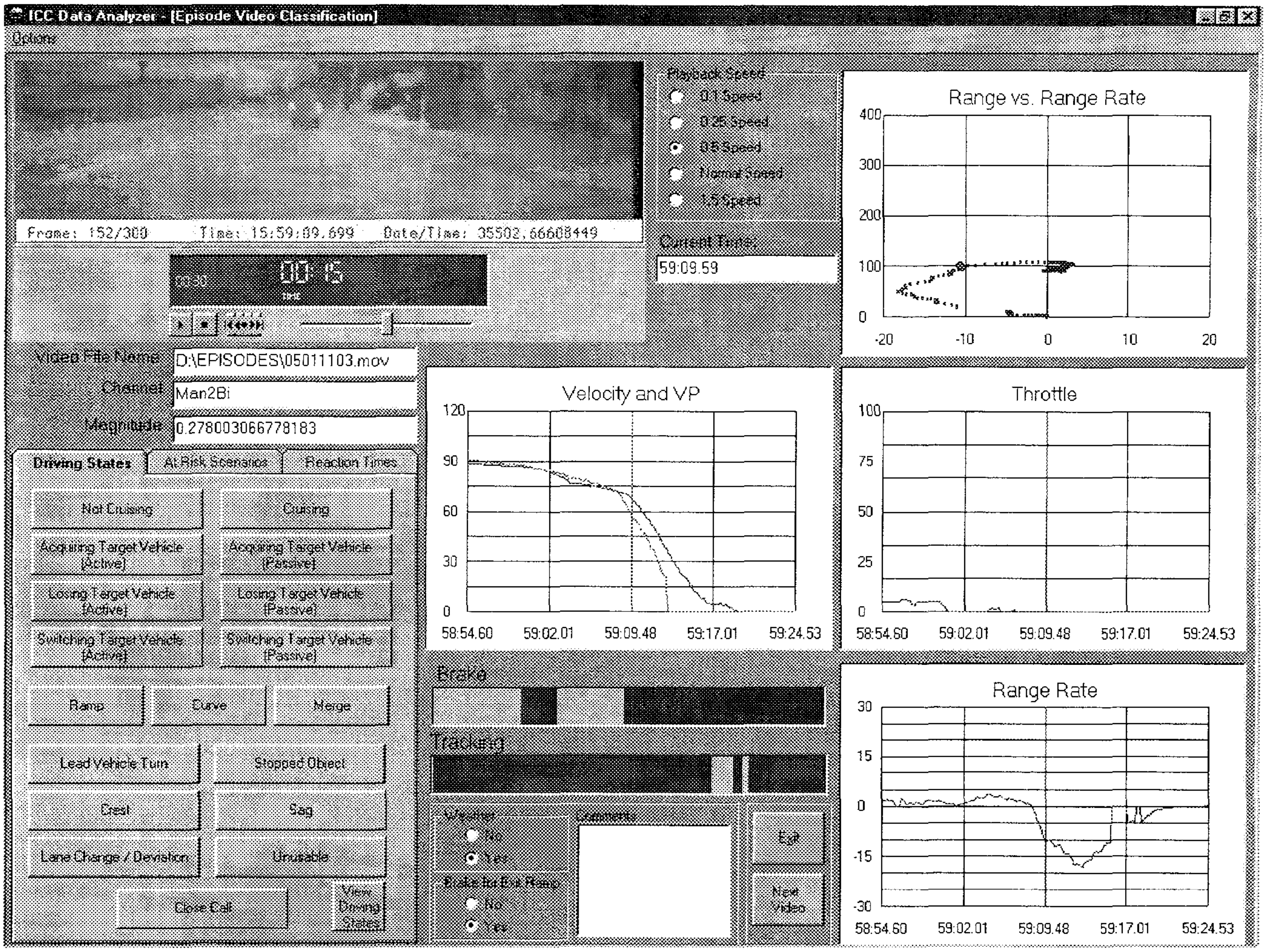

Figure 1. Sample Episode Screen.

Transitions

Three transitions have been identified as being of interest to this study. They are:

- acquiring a target vehicle;
- dropping a target vehicle; and
- switching target vehicles.

By definition, all three of these transitions require a lane change to occur to qualify as a transition. If the lane change was performed by the ICC driver/vehicle then the transition is classified as being active. If the lane change was performed by another vehicle, then the transition is classified as being passive.

Scenarios of Special Interest

Eight driving situations have been identified as being of special interest to this study. They are:

- driving on ramps;
- "not cruising" on curves;
- freeway merges;
- lead vehicle turns (left or right);
- stopped object on roadway;
- "not cruising" on crests;
- "not cruising" in sags; and
- unexplained lane changes or deviations.

Buttons are available on the Episode Video Interface to tag these scenarios of special interest.

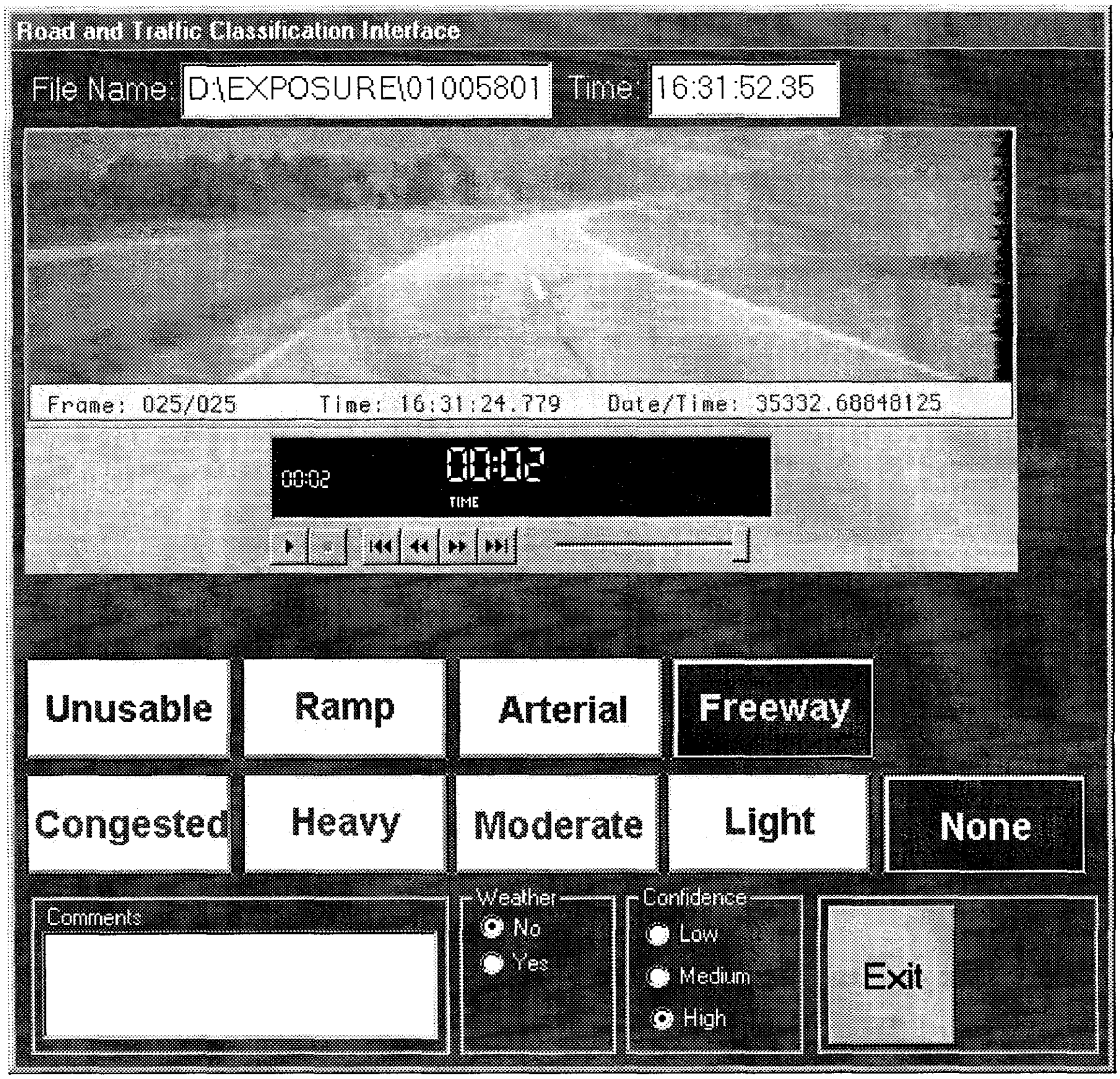

Figure 2. Sample Exposure Screen.

Close Calls

One of the primary areas of interest in the video analysis is the occurrence, severity and proximity of close calls. If the analyst determines that the video clip was triggered (brake intervention, near encounter, concern) due to a potential interaction with another vehicle or object, or a near run-off the road event, then the "close call" button is selected. Figure 4 provides an outline of the procedure for identifying close calls and assigning severity and proximity values to them.

Once the "close call" button has been selected, a screen comes up that allows the analyst to identify the type of close call and proximity of the close call event. This identification is performed using the on-screen Close Call Event Tree. (For description see reference for ICC Field Operational Test Video Classification Training Manual.) The analyst must move through the tree until the appropriate description of the close call is found. Upon selecting the appropriate close call description, severity is automatically assigned by the interface and displayed on the screen. The severity assigned is a function of the vehicle speed. This severity measure is the potential severity in the event of a crash. The severity values range from 1 to 4, where 1 is minor, 2 is marginal, 3 is critical and 4 is catastrophic. Proximity is a subjective measure of "how close" the close call event was to a crash. The analyst assigns the proximity rating

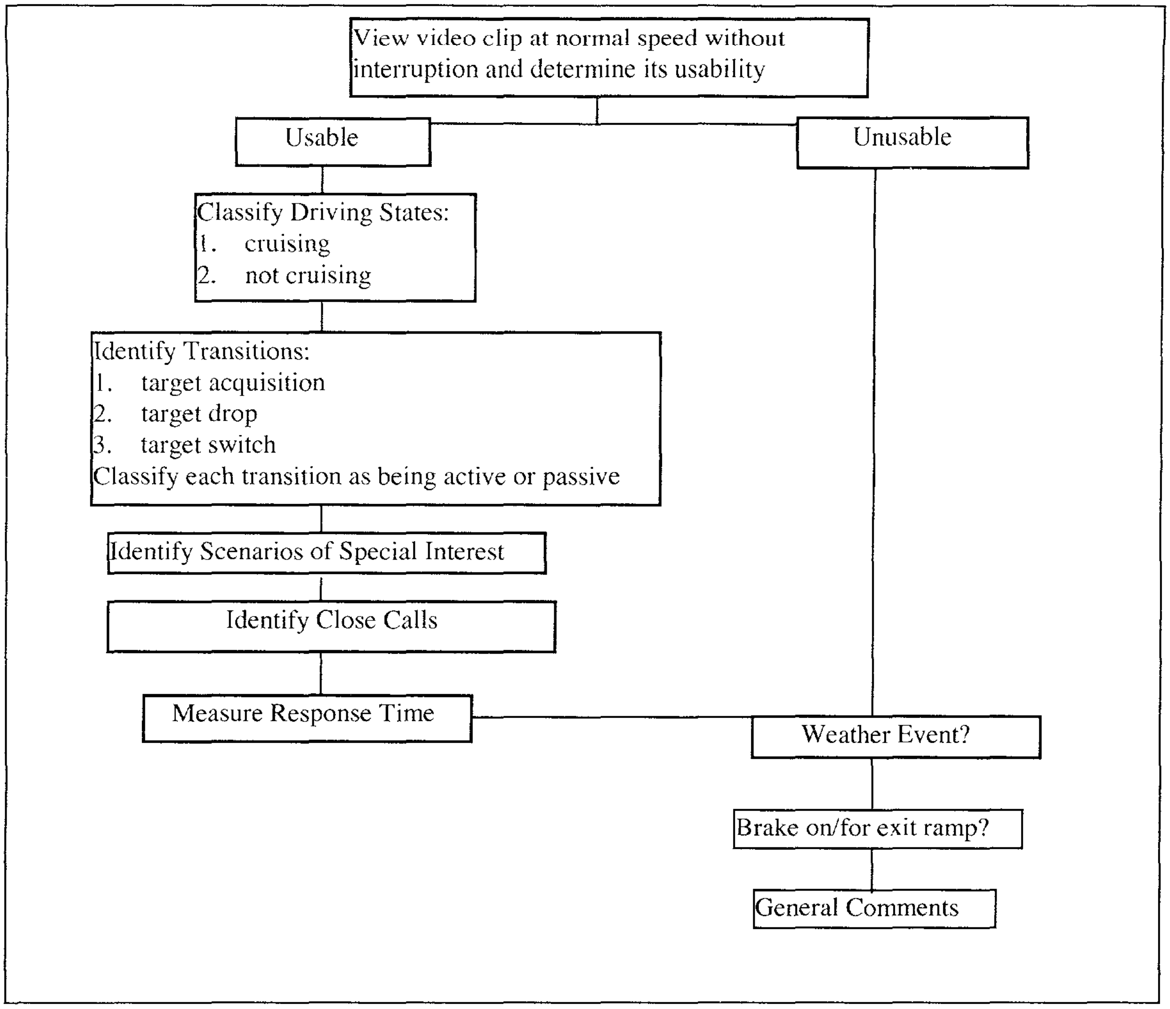

Figure 3. Video Data Classification Protocol.

according to the following scale (McGehee, 1996):

- Near miss - The driver is required to take immediate evasive action in order to prevent a crash.
- Hazard Present - The close call occurs when an object is present in the environment - requires that the object is in close enough proximity to represent a hazard to the ICC vehicle, but not close enough that an immediate evasive action must be taken to avoid it.
- No Hazard Present - The close call occurs when no close proximity obstacle is present in the environment.

Proximity is assigned by selecting the appropriate proximity button on the close call screen.

Driver Response Times

Another primary area of interest in the video analysis is the measurement of driver response times. Response times are measured for events in which there is a measurable stimulus that generates a measurable response from the driver of the ICC vehicle. The response time is recorded by pressing a series of buttons to time stamp the stimulus and response and to record the time once the analyst is confident that he/she has accurately captured the event. In recording a response time, appropriate stimulus and response descriptions must be selected. Choices for the stimulus include:

- lead vehicle brake lights come on (visual);
- lead vehicle deceleration with no brake light (marked decrease in Vp);
- obstacle appears suddenly in ICC vehicle's path;
- cut-in where slower vehicle crosses lane line into ICC vehicle's lane; and
- other.

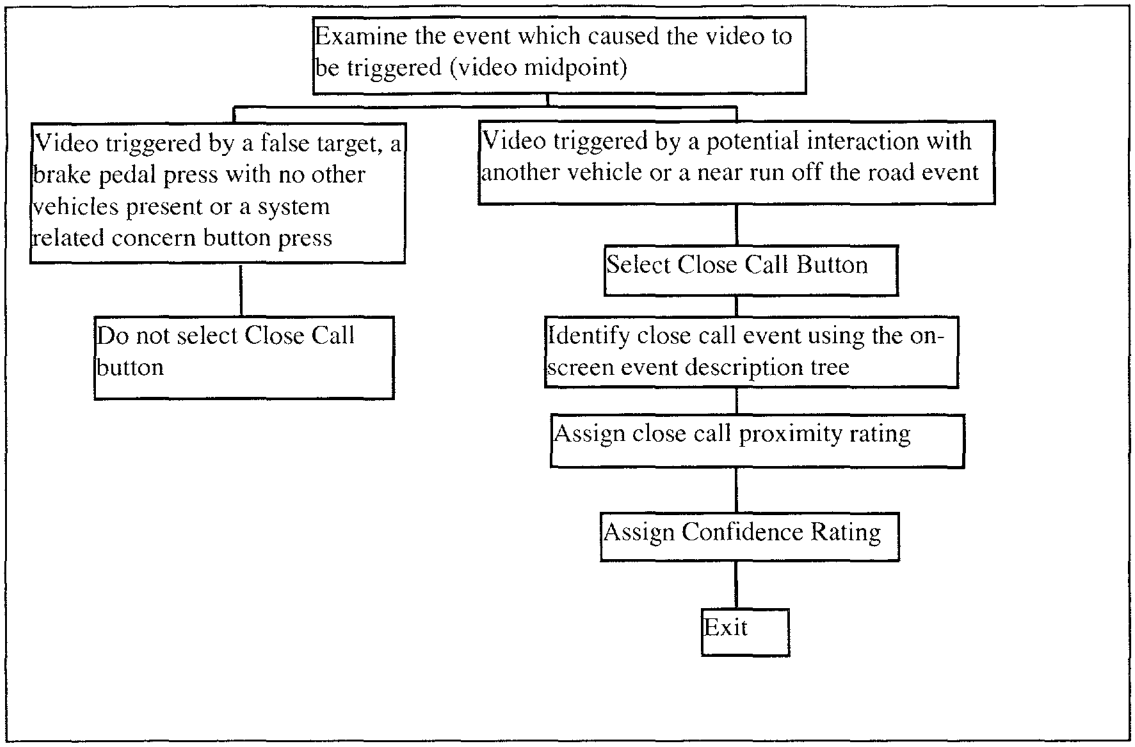

Figure 4. Close Call Classification Procedure.

If "OTHER" is selected, the analyst is required to provide a short description of the stimulus. Choices for the response include:

- ICC driver presses the brake pedal (brake variable goes from gray to blue);
- marked deceleration begins (noticeable decrease in V), or throttle off (1 to 0);
- start of lateral maneuver, e.g., driver swerves; and
- other.

Again, choice of the "OTHER" category requires inclusion of a text description of the response type. The video analyzer may record more than one response time for a given event since different combinations of stimuli and responses can occur.

Weather

One of the final steps in episode video classification is to determine whether or not the video displayed events of precipitation or road spray. If rain, snow, or road spray was visible during the clip then the analyst marks the clip as a weather event. It is valuable to tag these events as they can result in inaccurate data being recorded.

Brake On/For Exit Ramp

For video clips triggered by a brake intervention, the analyst is required to input whether or not the video was triggered by a brake on, or for an exit ramp. If the video was trigged when the ICC driver pressed the brakes to slow down in the deceleration lane of a exit ramp, or when he/she pressed the brakes while on the exit ramp, then the analyst tags the event as a brake on/for exit ramp. This information will allow the evaluation team to estimate what proportion of triggered events were of this type, and may provide insight into other potential trigger alternatives for future applications.

CLASSIFICATION – EXPOSURE VIDEO CLIPS

The general procedure followed by the video analyst in classifying an exposure video clip involves viewing the video clip and identifying the road class, the traffic density and whether or not the video clip shows evidence of precipitation or road spray.

With respect to road class, the analyst may choose between freeway, arterial, ramp and unusable. The unusable category is for video clips which show scenes of parking lots, driveways or other unusable scenes.

With respect to traffic density, the analyst may choose between none, light, moderate, heavy and congested. These categories correspond to levels of service (LOS) defined and depicted in TRB Highway Capacity Manual, 1994. This classification is intended as an informed estimate of congestion seen by the driver.

Identifying weather events in the exposure video clips serves the same purpose as identifying them in the episode video clips. It is valuable to tag these events as they can result in inaccurate data being recorded.

PRELIMINARY RESULTS

At the time this paper was prepared, video analysis on all 108 FOT subjects was not yet completed. Once the video analysis is completed and linked to the on-line numerical data base being developed by the evaluation team, interesting comparisons of event occurrences and driver behavior with and without ICC will be possible. So far, for 77 drivers, the video analyst has recorded:

- 4420 intervals cruising, 5893 not-cruising (7272 episodes);
- 5310 driving state transitions;
- 4606 close calls; and
- 866 driver responses.

Contingency (probability) tables of the driving state transitions, close calls, and response times are provided in Tables 1, 2 and 3, respectively.

Table 1.
Driving State Transitions - 77 Drivers

	transitions			
	target acquisition	target drop	target switch	**total**
active	0.052	0.194	0.316	0.562
passive	0.079	0.103	0.255	0.438
total	0.131	0.297	0.571	1.000

Table 2.
Close Calls - 77 Drivers

	proximity			
severity	no hazard present	hazard present	near miss	**total**
minor	0.002	0.002	0.001	0.005
marginal	0.000	0.011	0.000	0.011
critical	0.003	0.818	0.006	0.827
catastrophic	0.002	0.153	0.002	0.157
total	0.007	0.984	0.009	1.000

Table 3.
Driver Responses - 77 Drivers

	response				
stimulus	Brake	Throttle Off	Lateral Maneuver	Other	Total
Brake Lights	0.784	0.140	0.002	0.000	0.926
Deceleration - No Brake	0.002	0.000	0.000	0.000	0.002
Obstacle	0.000	0.000	0.000	0.000	0.000
Cut-in	0.012	0.006	0.001	0.000	0.018
Other	0.036	0.015	0.002	0.000	0.053
Total	0.834	0.161	0.006	0.000	1.000

OTHER POTENTIAL APPLICATIONS

The video analyzer has many potential extended applications. Three of these potential applications that are of particular interest to the evaluation team are introduced in the subsections below.

Identification of Potentially Critical Scenarios

Because video clips may visually identify major event types not necessarily tagged in the primary data stream, further classifications are possible beyond those currently automated. An example already tried is the classification of braking and near encounter episodes by distribution of magnitude of the triggering event. For one driver, 146 episode clips were reviewed for levels of deceleration achieved by braking or deceleration demanded by a near encounter. These episodes were sorted into histograms for each type of triggering event, with counts of occurrences in bins spanning associated levels of deceleration. The shape of the histogram provides a basis for the determination and selection of specific cases for detailed examination. The research objective here is to capture and analyze similar "high g" scenarios by scenario type for ICC vs. non-ICC driving.

Data Visualization

As data bases become larger and more complex, means that allow data visualization become very useful. The video analyzer allows visualization of several single and multi-dimensional data plots, synchronized with a visual record of what is actually occurring. This ability allows trends and relationships in and between data to be explored, and also allows study of data quality, consistency and accuracy.

Application to Other FOT Data

While the video analyzer was developed specifically for classifying, analyzing and exploring data collected for the ICC FOT, it can be relatively easily altered to handle data collected in other ITS FOTs. In addition to allowing collection of required measures and classification information, the application of the video analyzer was extremely helpful to the evaluation in examining data trends, data quality, data consistency and data accuracy. The video analyzer also provided a test bed for testing and validation of the other classification tools developed for the FOT evaluation. The video analyzer could easily serve a similar role in the evaluation of data collected in another ITS FOT or related area of study, e.g. rear end crashworthiness.

CONCLUSIONS

The ICC evaluation prompted the development of a video analyzer that allows video data to be easily classified for analysis. The video analyzer allows both video and plotted numerical data to be used in the data classification. The display of recorded numeric variables also aids in comparing how the system sees the world vs. how the driver sees the world and allows study of data quality, consistency and accuracy.

The video analyzer has many potential extended uses. Several of these extended uses include identification of potentially critical scenarios, data visualization, and integration of video and digital data from sources other that the ICC FOT.

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