Integrated Vehicle Instrument Simulations: i-ViS Initial Design Philosophy

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ABSTRACT

This paper positions the initial approach undertaken at the Digital Design Studio (DDS) within the recently initiated i-ViS project. The research activities of the DDS are driven by the imaginative use of new and emerging digital tools in the areas of visualisation and human-centred interaction.

There are growing trends towards the use of multiple graphical displays that present information to car drivers. Currently, however many functions in the vehicle user interface (dashboard, controls, audio & mobile phones) operate independently of each other. This leads to many situations where information flows can place inappropriate and potentially conflicting demands on the driver.

The situation is further compounded by the increasing safety concerns relating to inappropriate communication and infotainment events (e.g. mobile phones). Worldwide annual sales of telematics-enabled cars and light trucks will reach 27 million units by the end of the decade. A number of recent initiatives that seek to address these concerns are reported.

The i-ViS project is seeking to identify

- Potential logical groupings and couplings of instrumentation functions
- Existing and possible future visual, non-voice audio and vibrotactile-feedback cues
- Appropriate interrupt strategies and event responses

The paper concludes with an outline of the future aims of the research, the overarching objective of which will be to build a virtual demonstrator which will investigate:-

- the opportunity for more highly integrated control and feedback systems in vehicles.
- software algorithms which by prioritising or masking output, present appropriate and timely information thus reducing conflicting demands on the driver
- integration of a number of information functions into a programmable virtual display.

1. BACKGROUND: TRENDS, SAFETY & DESIGN ISSUES

Our work is motivated by the desire to develop solutions for the Human Machine Interface (HMI) within automotive vehicles which will contribute to improved safety whilst at the same time support customisation and product differentiation.

There has undoubtedly been a process of continuous development to the approach of delivering safety in the road transport sector. For convenience, we have chosen to conveniently split the activity into a number of phases or categories.

- Enhanced Structural Integrity
- Occupant Restraints & Intrusion Considerations
- Active Safety Systems
- Pro-Active Safety Systems

Today structural integrity initiatives, embodied in legislation, which are actively promoted through organisations such as EuroNCAP, and the widespread use of seat belts, have clearly delivered improved safety. Further improvements have been delivered through active restraint systems (such as pre-tensioning of seat belts) and airbags. More recently a growing number of systems have become available or are emerging which can be described as pro-active. These seek to provide additional advice to the driver of situations with a safety implication. These range from advisory information on low external temperatures and consequent skid risk, to more sophisticated collision avoidance systems. This last category of pro-active safety systems is central to our investigations in relation to how they can be integrated into the Human Machine Interface (HMI)

Recognising that the level of equipment in vehicles has increased immensely in terms of sophistication, complexity and importantly the level of additional information presented to the driver it is once again useful to classify this into a number of groupings, namely:-

- Driving Controls
- Cabin Controls
- Infotainment
- Safety/Security Advanced Driver Assistance Systems (ADAS)

These four groupings and their associated displays, which we collectively define as the HMI, have until fairly recently operated in a largely autonomous fashion. Indeed they are generally delivered through separate subsystems that have evolved with minimal integration from a communication and control system design perspective. This can perhaps best be illustrated by way of a number of example scenarios:

- Vehicle direction indicators operate independently of the information being presented and processed by a satellite navigation system (SNS).
- Traffic information presented through a Radio Data System (RDS) is not generally integrated into the SNS routing algorithm.
- Emerging systems such as adaptive intelligent cruise control (AICC) and Automated Collision Avoidance Systems (ACAS) are increasingly having to address how and where to present warnings and the level of integration (if any) with existing driving controls such as the accelerator brakes and steering.

- Communication and infotainment events (e.g. mobile phones, SMS text messaging and Internet location specific data) fail to recognise the primary input tasks being performed by the driver prior to generating the interrupt situation.
- Automatic adjustment of cabin controls (temperature & ventilation) could have a role to play in systems which monitor driver fatigue

These and other issues present us with an ideal opportunity to fundamentally re-appraise the interface presented to and the interaction with the driver.

It has been recognised for some time that the growing volume of information and the opportunities for distraction from the main driving task can have a detrimental impact on safety. Wang et al [1] pointed out that driver inattention is the leading primary cause of accidents (25-56%). Meanwhile, there are a growing number of graphical displays [2] being used to present information to the driver. As has already been highlighted many functions in the vehicle user interface (dashboard, controls, audio & mobile phones) operate independently of each other. This leads to many situations where information flows can place inappropriate and potentially conflicting demands on the driver. In particular, there are growing safety concerns relating to inappropriate communication and infotainment events (e.g. mobile phones). Worldwide annual sales of telematics-enabled cars and light trucks are predicted to reach 27 million units by the end of the decade [3].

Bruce et al. [4] point out that, "the proliferation of in-vehicle displays is growing despite the fact that references to driver's overload from visual information have existed in the research literature for several decades." The EU project COMUNICAR [5] has developed rules for allocating inputs and outs to sensory modalities. These cover issues such a distinguishing between primary driving tasks, the complexity of the information, and the time dependency or validity of the information and the need to attract the driver's attention to perform a specific course of action.

A fundamental governing principle that we will use to guide our research is a firm belief that information should always be presented in a timely and appropriate manner with a view to reducing the possibilities of information overload. We will also seek to explore the most appropriate combination presentation of information through the multi-modal interfaces of: -

- Visual
- Tactile
- Non-Voice Audio
- Speech

This approach will be further informed by the European Commission recommendations that HMI for an in-vehicle information and communication systems [6] should address the following critical issues:

1. How to design and locate information and communication systems in such a way that their use is compatible with the driving task?
2. How to present information so as not to impair the drivers' visual allocation to the road scene?
3. How to design such a system interaction that the driver maintains under all circumstances safe control of the vehicle, feels comfortable and confident with the system and is ready to respond safely to unexpected occurrences.

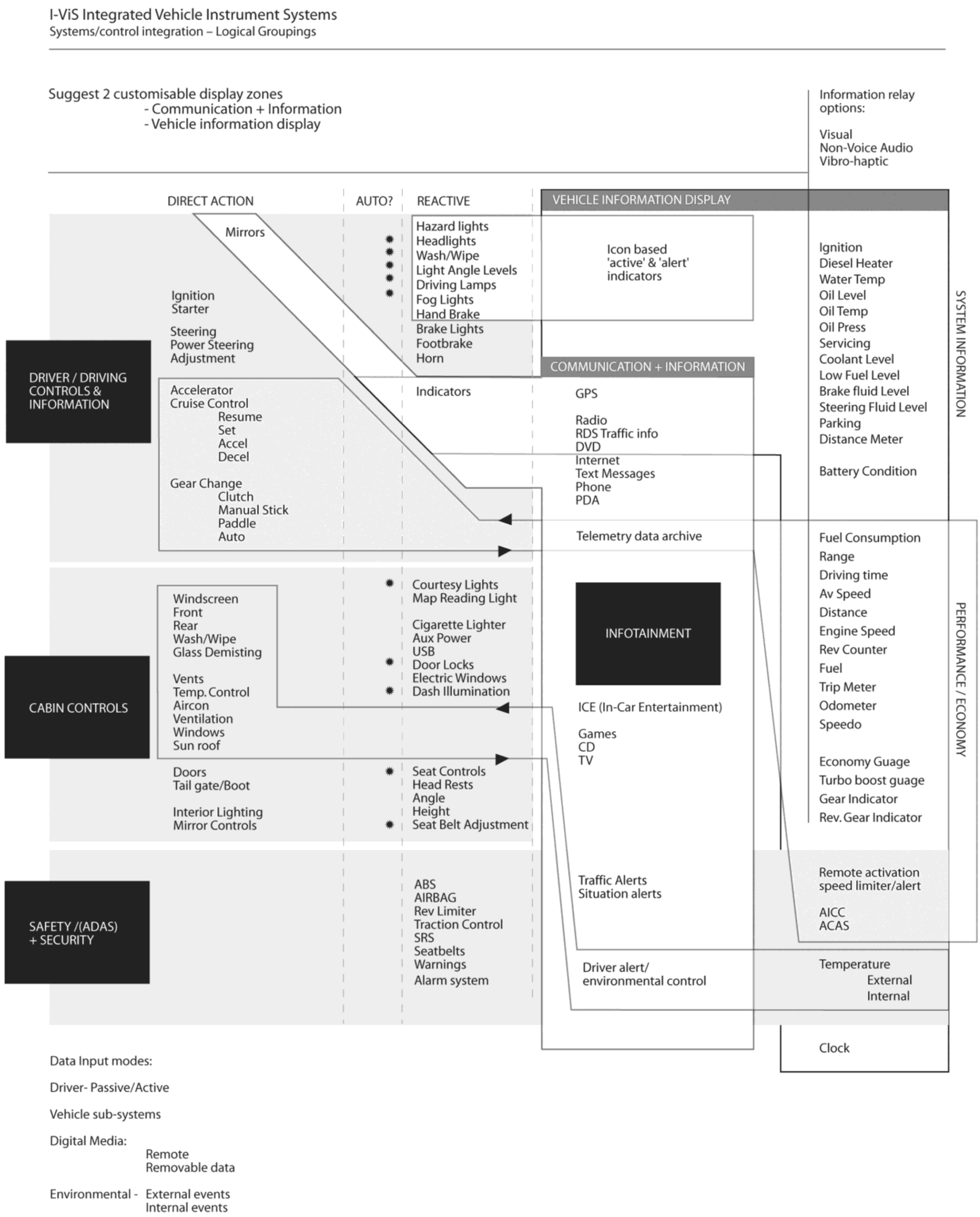


Figure 1: i-ViS Systems/cpmtrol integration – Logical Groupings

2. LOGICAL COUPLING OF INSTRUMENTATION FUNCTIONS

Whilst recognising the work already carried out in this field, our approach was to conduct a series of brainstorming sessions which sought to list and categorise the various controls and instrumentation functions of a vehicle based on the collective driving experiences of the research team. These were categorised under the four HMI groupings which we previously defined namely: driving controls, cabin controls, infotainment, and safety/security (ADAS) systems. At this stage, we did not unduly concern ourselves with any duplication indeed it was positively encouraged. We looked at the HMI from the perspective of actual controls, switches indicators and displays. Subsequently, we analysed and structured this information to identify possible logical groupings and integration modes as summarised in Figure 1.

This work also led to the concepts summarised in Figure 2, where the inputs were classified from four sources. Those arising directly from driver actions, those arising from infotainment events, those initiated or prompted by a vehicle sub-system such a low fuel warning and lastly those stemming from an external event such as a satellite navigation system or a collision-avoidance system.

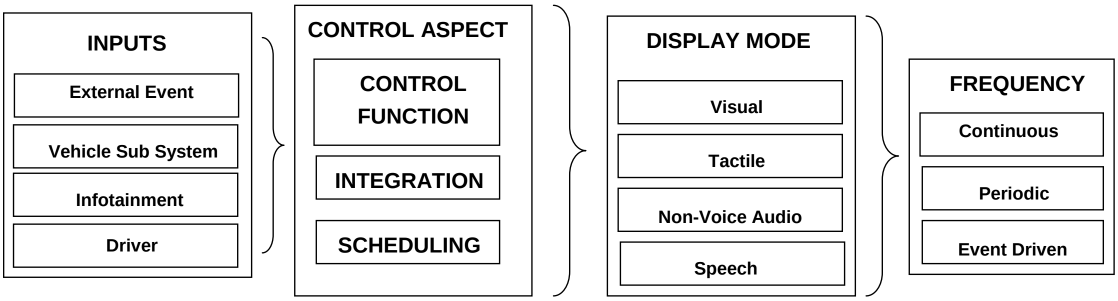


Figure 2. Multimodal Integrated HMI Consideration

3. POTENTIAL FOR MULTI SENSORY INTERFACES

The key multi-modal interfaces that we are investigating in the i-ViS project have already been defined earlier in this paper. Figure 2 builds on this by defining the frequency of display for any given mode. Information such as the speed of a vehicle is typically required by legislation to be displayed continuously. Other information such as coolant temperature, which is often visible constantly, could potentially be displayed on a periodic basis. Whilst there is yet another class of information which would most likely be shown in response to a specific situation such as low brake fluid level, which we have termed event-driven

A further level of granularity could include HMI issues such as varying the size and colour of visual graphics. Work by the US National Highway Traffic Safety Administration[7] on automotive collision avoidance systems have shown that improvements in braking reaction times can be achieved by the use of display sequences that exhibited a looming quality (expanding visual images representing imminent collision) illustrated in Figure 3.

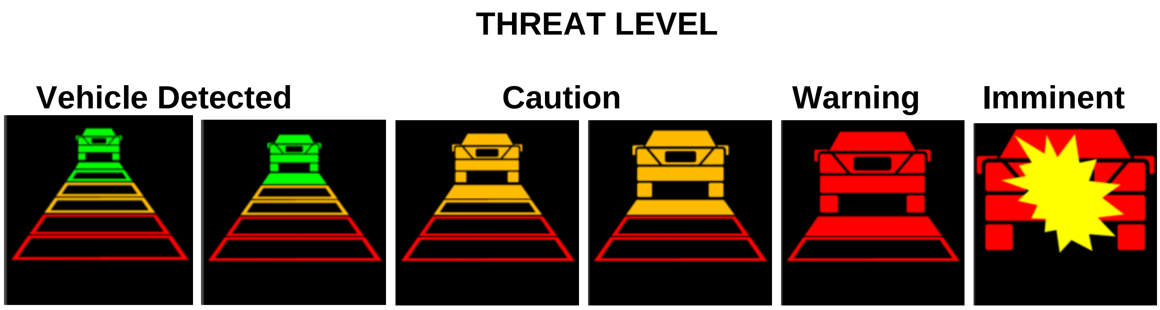


Figure 3. The three stage looming-plus-scale (LS) displays used plus “vehicle detected” icon

Whilst this is an interesting approach we would wish to consider other aspects such as the psychological interpretation of the colours and particularly the effects of learned responses over a long period of time before advocating such a system.

Further information could also be conveyed to the driver by varying the rate of display of information. With non-voice audio interfaces, multiple tasks, typical of driving scenarios, can be potentially handled by varying the volume, pitch or spatial positioning of the sound to convey specific information that would not add to the visual workload of the driver [8]. To avoid masking [9] several sound patterns can be spread across a range of frequencies.

Several research studies have shown that vibrotactile technology can be utilised to provide additional feedback information to the driver. In particular, experiments conducted by Lindeman R. W., Yanagida Y. [10], into the use of vibrotactile cues for near-field haptics in virtual environments, showed that 84% of the tested users identified correctly the location of vibrotactile feedback. The vibrations, lasting for only one second, were generated by a single tactor of a 3-by-3 array on the back of the seat (Figure 4, 5). The users could also recognise different intensities of vibrotactile feedback. [10]

Such mechanisms could potentially be integrated in a vehicle and collaborate efficiently with a number of subsystems. We may return to explore this area in more detail as our research develops.

Figure 4, 5. Seats with 3-by-2 and 3-by-3 array of tactors.

4. EVENT DRIVEN RESPONSES AND INTERRUPT STRATEGIES

Driving processes require fast and accurate decision-making as well as high attention levels. A number of real-time information systems are used as standard equipment on new vehicle models in order to assist the driver. Studies conducted in real-time conditions, testing the increased visual load presented by in-vehicle displays [12] show that the driver could be easily distracted or misinformed by inappropriate information. The proliferation of incoming information can significantly increase the cognitive workload affecting human spatial gaze concentration [13].

In order to minimise the total amount of information that could overload the driver, it is necessary to introduce a system to provide event-driven and real-time appropriate interrupt strategies. The word *"appropriate"* underlines the need of a subsystem, which identifies, analyses and provides the driver with information relevant to his driving state. Smith et al proposed that the driving states can be defined in four different risk levels - low risk, conflict, near-crash, and crash imminent [14]. Adopting these definitions of driving current state, we further propose to prioritise the incoming information based on the three main categories defined in Figure 2, as an external event (traffic-environment based), vehicle subsystems and the general information presented to the driver.

Our initial thinking which we wish to test is summarised in Figure 6, Proposed i-ViS Event Response and Interrupt Strategies. By giving priority initially to the external events (traffic information as GPS, automatic collision notification, vehicle positioning and traffic fluency) we address the fundamental issue of the driver's safety. As a second priority, we can present vehicle sub-system information to the driver according to the urgency. Other infotainment information such as the internet, mobile or entertainment can be provided to the driver dependant on the driving state risk status.

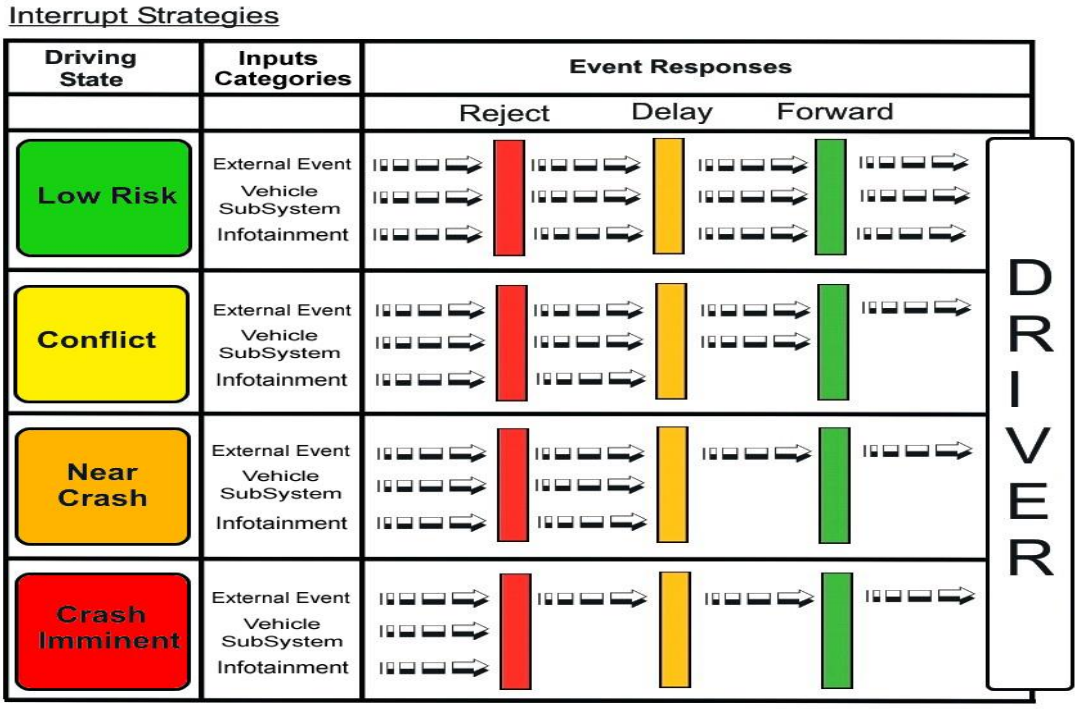
We have taken the risk concepts proposed by Smith et al, whereby for example at the low-risk state, considered to be the base level, we would permit all the incoming information to be forwarded to the driver within the information categories of external events (traffic etc), vehicle subsystems and driver related. Alternative strategies in the other three driving states could be delivered by defining a series of driver control events and identifying rules which apply, when for example the driver is indicating, braking or changing lane, or indeed when such an event can reasonably be predicted to be required within a given short time frame. An example of a predictive event might be cross-correlation with the time to collision (TTC) measuring system [15], where further information is delayed until the driver's response to a possible situation becomes clear. In this way, by providing only important and necessary information it should be possible to improve the driver's reaction time. In many circumstances, the quantity and relevance of the incoming information from the subsystem could make a distinctive difference between a successful avoiding manoeuvre and a collision.

The driver's actions can be informed through system interrupt strategies by using specific event responses as rule-based filters. By defining the utility of these filters we can apply three main levels of filtering as event responses:

- Forward: vital information to the driver,
- Delay: less important information and
- Reject: irrelevant information depending always on the driving state.

As an example of the event response filtering, the system could immediately forward vital information to the driver about the near-crash, delay incoming GPS data and reject irrelevant information such as an incoming phone call.

Figure 6. Proposed i-ViS Event Response and Interrupt Strategies



5. FUTURE RESEARCH

The next phase of our work will concentrate on developing a virtual prototyping environment which supports our event-based approach and simulates possible integration strategies. These alternative interfaces will be evaluated against a set of assessment criteria and the most promising tested with a range of drivers.

In this way we will be able to assess:-

- software algorithms which by prioritising or masking output, present appropriate and timely information thus reducing conflicting demands on the driver.
- integration of a number of information functions into a programmable virtual display.

We will also seek to inform our thinking through dialogue with a number of automotive suppliers. It is anticipated that preliminary conclusions may be drawn from our digital simulations but that full assessment will require incorporation of our concepts into a fully functioning driving simulator. In the future, we will be seeking opportunities to participate in collaborative projects in the area of Intelligent Transportation Systems either EC funded or in conjunction with industry through EPSRC.

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GLOSSARY

ADAS	Advanced Driver Assistance Systems
EURONCAP	European New Car Assessment Programme
HMI	Human Machine Interface
i-ViS :	Integrated Vehicle Instrument Simulations
SNS	Satellite Navigation System
RDS	Radio Data System
AICC	Adaptive Intelligent Cruise Control
ACAS	Automated Collision Avoidance Systems
SMS	Short Message Service
COMUNICAR	Communication Multimedia Unit Inside CAR
AIDE	Adaptive Integrated Drive Vehicle Interface
TTC	Time To Collision